*Annual Geological Conference '96*
*June 8–9, 1996, Kota Kinabalu, Sabah*

# The settings and styles of gold mineralization in Southeast Asia

S.L. GARWIN

Newmont Southeast Asia Limited
Wisma Standard Chartered Bank
14th Floor, Jl. Sudirman Kav. 33A
Jakarta 10220, Indonesia

**Abstract:** Gold mineralization in Southeast Asia is associated with a wide range of deposit styles. This study incorporates 90 gold and copper-gold deposits, including porphyry, skarn, carbonate-base metal-gold, volcanic-hosted high- and low-sulfidation epithermal, quartz lode, volcanogenic massive sulfide and disseminated sediment-hosted. The combined past production and current resources of these deposits exceeds 6,800 tonnes of gold and 50 million tonnes of copper. The majority of the gold is contained in porphyry (64%), low-sulfidation epithermal (17%), carbonate-base metal-gold (7%) and skarn (4%) deposits. Approximately 90% of these deposits (> 95% of the gold) are associated with middle to late Cenozoic magmatic arcs.

Fourteen major magmatic arcs and several secondary arcs of Cenozoic age form a complex border to the Sundaland craton and the northern margin of the Australian platform. This volcano-plutonic chain extends more than 12,000 km from Taiwan in the northeast, through the Philippines and Indonesia, to Myanmar in the northwest. The arcs are constructed on basement formed from oceanic and continental crust. In northern Taiwan, gold deposits are hosted by Pleistocene intrusions. The Philippines and Indonesia hold more than 90% of the known gold in the region. This mineralization is contained in deposits which cluster along short sectors of middle Tertiary to Pleistocene arcs. In East Malaysia, gold is related to Neogene intrusions and in northcentral Myanmar, mineralization is associated with a middle to late Tertiary arc sector. Porphyry and epithermal mineralization styles predominate, while skarn, carbonate-base metal-gold, sediment-hosted and volcanogenic massive sulfide/exhalative deposits are less abundant.

Mainland Southeast Asia is a composite of four major crustal plates or terranes, each defined by a series of tectonostratigraphic belts formed upon pre-Cenozoic continental basement. These include cratonic platforms, fold belts, magmatic arcs, volcano-sedimentary rift basins, and metamorphic terrains. Late Paleozoic to Mesozoic volcano-plutonic arcs parallel fold belts which have developed along continental margins adjacent to intra-plate collision zones. Mineralization within these fold belts is commonly localized within anticlines or in structurally complex regions. Other prospective geological settings are suture zones, major strike-slip faults, structural domes and the margins of rift basins. Gold mineralization occurs in quartz lode (common), skarn and porphyry (subordinate), and disseminated sediment-hosted, massive sulfide and volcanic-hosted epithermal (minor) systems.

Gold mineralization in Southeast Asia is spatially and temporally related to intrusions and volcanic centers. Porphyry, skarn and high-sulfidation epithermal deposits are closely related to intrusions emplaced at shallow depths. Low-sulfidation epithermal systems, including vein, stockwork and minor disseminated styles, typically are located within or adjacent to volcanic centers. Carbonate-base metal-gold deposits occupy diatreme settings in the deeper portions of low-sulfidation epithermal systems. Disseminated sediment-hosted deposits occur in calcareous rock sequences in both proximal and distal settings to intrusions. Volcanogenic massive sulfide and exhalative deposits are developed in sea floor extensional settings. Quartz lodes are typically structurally-controlled and hosted by pre-Cenozoic metasedimentary and sedimentary rocks.

## INTRODUCTION

Southeast Asia extends approximately 4,000 km from latitude 15°S to 25°N and 5,500 km from longitude 90°E to 145°E (Fig. 1). Mainland Southeast Asia forms approximately 45% of the landmass of the region with the remainder divided between numerous islands that comprise the extensive archipelagos of Indonesia and the Philippines. The size of these islands ranges from that of Borneo, the third largest in the world, to small masses of less than one square kilometer. The physiography is varied and punctuated by mountains which reach 5,030 m (Puncak Jaya) in the highlands of Irian Jaya, Indonesia. The countries which comprise Southeast Asia are Brunei, Indonesia, Kampuchea, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and

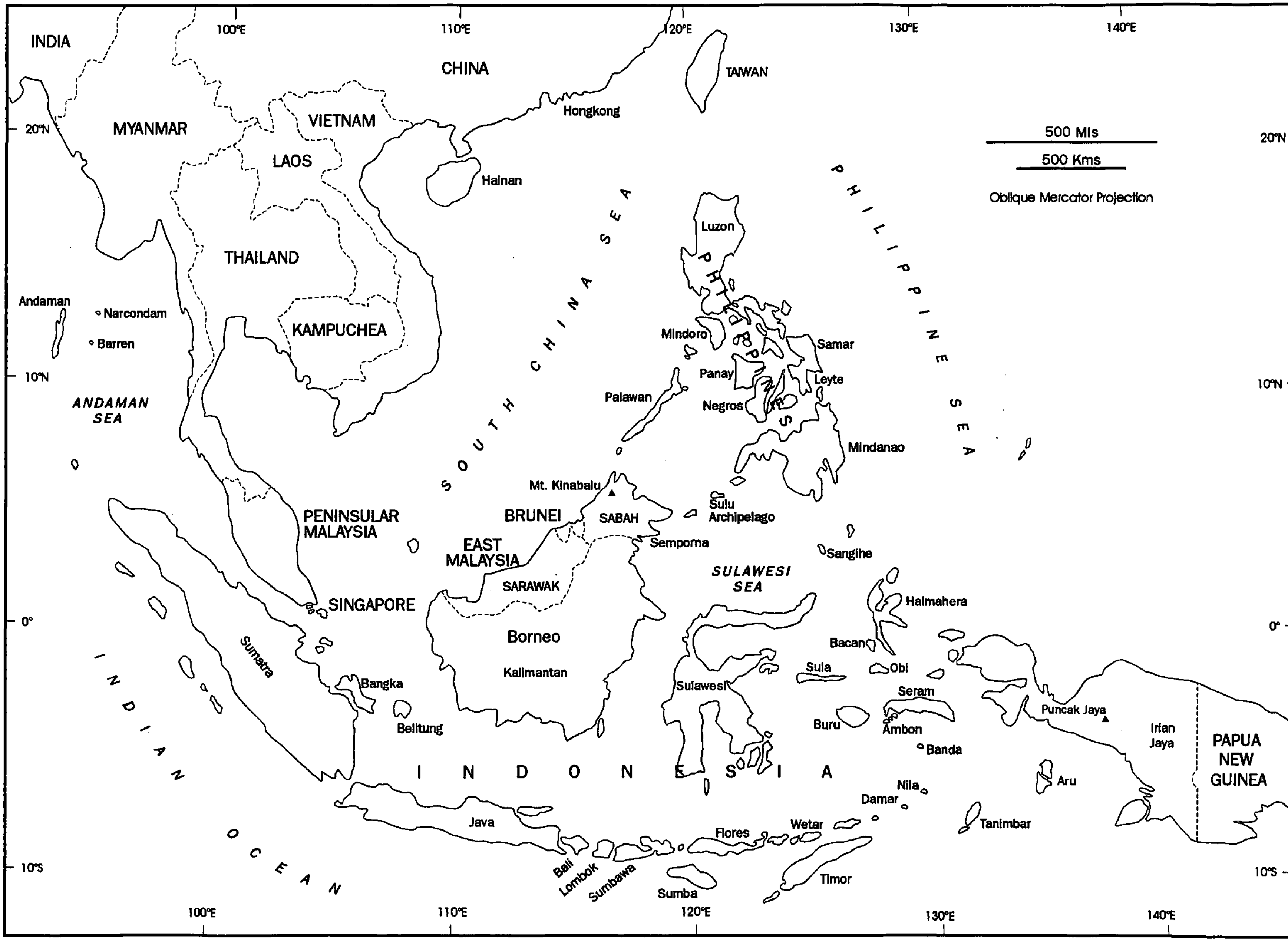


**Figure 1.** Location map of Southeast Asian countries and islands, modified after Hutchison (1989).

Vietnam. Southern China, technically part of Southeast Asia, is not included in this paper.

The primary aim of this paper is to briefly describe the geologic settings and differing styles of gold mineralization in Southeast Asia. Gold is most abundant in the Cenozoic magmatic arcs of the Philippine and Indonesian archipelagos. Significant gold deposits which occur in pre-Cenozoic metallogenic belts in mainland Southeast Asia are placed in context of tectonostratigraphic terranes and magmatic arcs. Descriptions of deposit styles and grade-tonnage distributions comprise the focus of the paper.

I have attempted to accurately compile the work of other geoscientists into a uniform base in the hope that these data will be of use to exploration geologists working in Southeast Asia. Interpretation of others' data and estimates of deposit grade and size are included when necessary.

This paper is a condensed version of a more comprehensive work currently in preparation. Therefore, the text explains only the major aspects illustrated in the figures.

## Historic Mining Activities

Mining of placer and lode gold deposits began in ancient times in the majority of the countries in Southeast Asia. Significant historic mining sites and regions are illustrated in Figure 2.

In northern Taiwan, the Chinkuashih copper-gold district produced over 92 tonnes of gold from 1898 to 1987 (Tan, 1991). In the Philippines, significant production was achieved prior to the second world war from gold districts in Baguio, Paracale, Masbate and Surigao. The Baguio district has produced more than 800 tonnes of gold from lode gold and porphyry copper deposits (Mitchell and Balce, 1990). In Indonesia, nearly 80 tonnes of gold was recovered from the Lebong Tandai and Lebong Donok lodes in the Bengkulu district of Sumatra during 1896 to 1941 (van Bemmelen, 1949). The Paleleh and Totok (Ratatotok) districts of northern Sulawesi produced over 13 tonnes of combined gold from lode and eluvial deposits (van der Ploeg, 1945).

In Peninsular Malaysia, the Raub-Australian lode produced approximately 30 tonnes of gold from 1889 to 1961 (Lee *et al.*, 1986). In the Bau district of Sarawak, 31 tonnes of gold were recovered from primary and eluvial deposits between 1899 and 1921, largely from the Tai Parit open pit (Wilford, 1955). The remaining countries of Southeast Asia have sustained limited gold production from alluvium in the Myitkyina district of Myanmar and lode deposits in southern Thailand (Toh Moh), Kampuchea (Bo Sup Trup) and Vietnam (Bong Mieu). No significant production is recorded for Laos. However, ancient to recent artisinal mining has exploited alluvium in several localities.

## Recent Developments

There has been a marked increase in the exploration and development of mineral resources in Southeast Asia during the past decade. These activities were undertaken by national and foreign companies and on a small-scale by local miners. Significant technical work was accomplished by Southeast Asian geological survey groups and bureaus of mines, the United Nations, the Metal Mining Agency of Japan and overseas geological survey organizations.

Extensive exploration in Indonesia since the middle 1980's has led to significant discoveries. Several large gold mines have been developed, including Grasberg (copper-gold), Kelian, Mesel, Mt. Muro and Wetar. Recent discoveries include the Batu Hijau copper-gold deposit and the Busang gold deposit. Indonesia is currently the focus of a major gold boom. Foreign and local companies have lodged claims through out the archipelago. The recent history of minerals exploration and development in Indonesia is well documented by van Leeuwen (1994).

Significant discoveries in the Philippines during the past decade include the Dinkidi copper-gold deposit, the Co-O lode, and the Diwalwal and Compestela gold rush areas. The passing into law of a new minerals code in 1995 has stimulated investment and initiated a rush to stake claims through out the country.

Exploration in mainland Southeast Asia, including Laos, Malaysia, Myanmar, Thailand, and Vietnam is significant, but to a lesser extent than exploration in Indonesia and the Philippines. This likely reflects the lesser abundance of large gold discoveries in the past and/or challenges presented by mining legislation, or the lack thereof. The mineral codes and laws in each of these countries either have been modified during the past five years or are currently in the process of revision. Mineral agreements have been signed, exploration undertaken and small to moderate sized gold deposits discovered, the largest of which is Xepon in southcentral Laos, the discovery of which was announced in 1995.

## Gold Endowment and Recent Production

Southeast Asia is moderately well endowed in gold resources. Figure 3a shows the number of deposits containing 10 tonnes of gold resource (including past production) or more in each country. The enhanced endowments of the Philippines and Indonesia are clear, and rank far above the other countries in the region. Figure 3b illustrates the

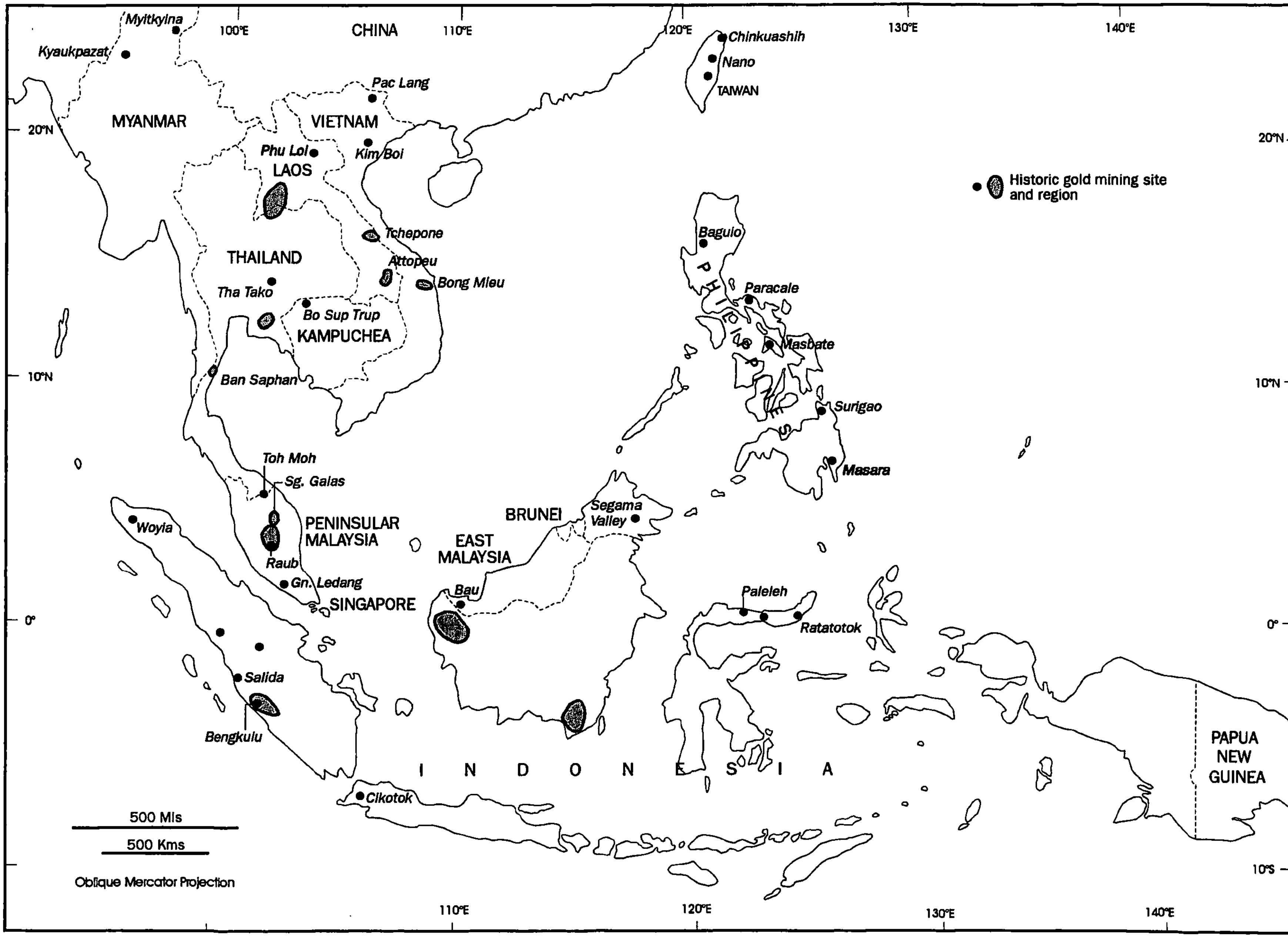


**Figure 2.** Significant historic mining sites and regions in Southeast Asia, compiled from several sources, including van Leeuwen (1994).

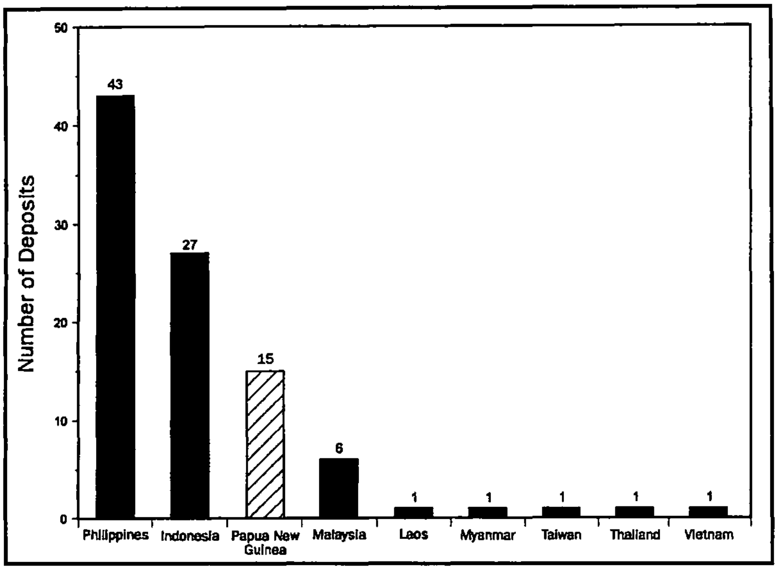


**Figure 3a.** Number of Southeast Asian deposits which contain gold resources in excess of 10 tonnes (including past production), by country. Papua New Guinea is included for comparison.

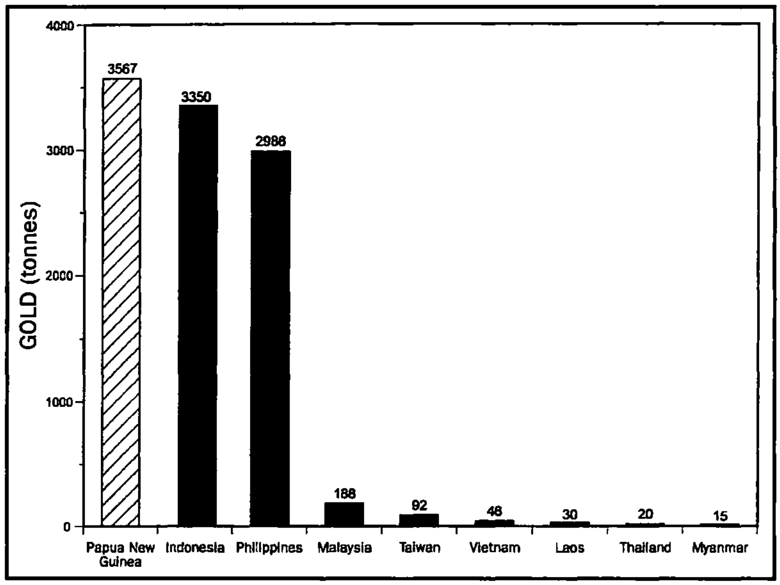


**Figure 3b.** Gold endowment of Southeast Asian deposits which contain gold resources in excess of 10 tonnes (including past production), by country.

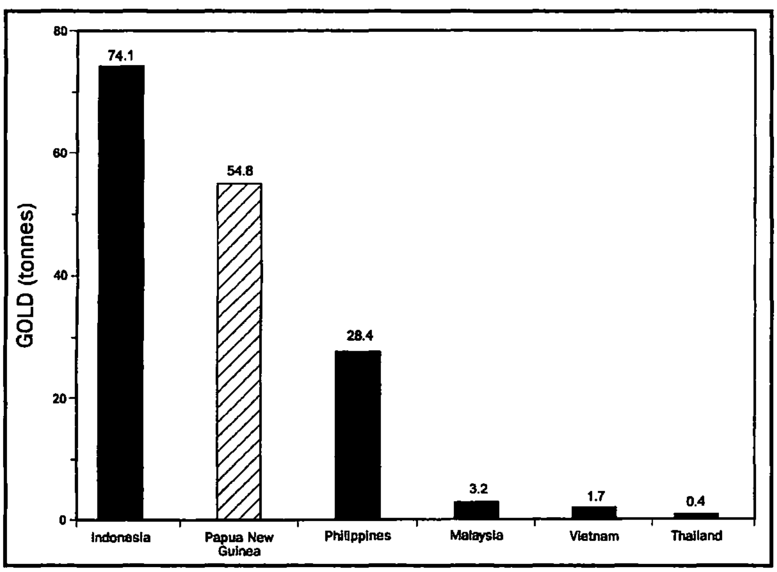


**Figure 3c.** Gold production from Southeast Asian countries in 1995, after Goldfields (1996).

total gold content for each country, determined from the deposits indicated in Figure 3a. Again, the overwhelming significance of Indonesia and the Philippines is apparent. However, it is important to note that approximately 50% of Indonesia's gold lies in the Grasberg copper-gold deposit. Gold lodes in the Baguio district of the Philippines constitute more than 18% of the total gold endowment of the Philippines. Papua New Guinea, considered to be richly endowed in gold and copper resources, contains a slightly greater gold abundance than those of Indonesia and the Philippines. The deposit database from which the Southeast Asian country figures are derived is included in Appendices 1 through 4.

The official gold production in Southeast Asia for 1986 to 1995 is predominately from the Philippines (340 tonnes), Indonesia (313 tonnes), Malaysia (32 tonnes) and Vietnam (9 tonnes), with only minor production from the remaining countries (Goldfields, 1996). As a comparison, Australia's official gold production for the same period totals 2,026 tonnes and that of Papua New Guinea totals 483 tonnes. Southeast Asian gold production in 1995 totaled 107.8 tonnes. The majority of this amount (Fig. 3c) was produced from Indonesia (74.1 tonnes, 69%), followed by the Philippines (28.4 tonnes, 26%), Malaysia (3.2 tonnes, 3%) and Vietnam (1.7 tonnes, 2%). For the same year, Australian gold production was 254 tonnes and that of Papua New Guinea was 54.8 tonnes.

## CENOZOIC MAGMATIC ARCS OF SOUTHEAST ASIA

Fourteen major magmatic arcs and several secondary arcs of Cenozoic age form a complex border to the Sundaland craton and the northern margin of the Australian platform (Fig. 4). This volcano-plutonic chain extends more than 12,000 km from Taiwan in the northeast, through the Philippines and Indonesia, to Myanmar in the northwest. The arcs are constructed on geologic basement formed from oceanic and continental crust. The geometries of individual arc segments are complex, and are the product of subduction, locally involving polarity reversals, obduction, arc-arc and arc-continent collisions, rifting and transcurrent faulting. Hamilton (1979) and Hutchison (1989) provide comprehensive reviews of the tectonic elements and processes which characterize the region. Hall (1995) presents plate tectonic reconstructions for the Tertiary. Previous descriptions of various magmatic arcs in the context of gold mineralization include those of Mitchell and Leach (1991) for the Philippines and Carlile and Mitchell (1994) for Indonesia.

The ages of the magmatic arcs span from the late Mesozoic through the Cenozoic time. However, gold and related copper mineralization occur almost exclusively in those arc sectors developed during the middle to late Cenozoic (Figs. 5 to 9). In northern Taiwan, gold deposits are hosted by Pleistocene intrusions. In the Philippines and Indonesia, gold deposits cluster along short sectors of middle Tertiary to Pleistocene arcs. In eastern Malaysia, gold mineralization is related to Neogene intrusions and in northcentral Myanmar, gold is associated with a middle to late Tertiary arc sector. The primary reason for the great abundance of gold deposits in the middle Tertiary to Pleistocene arcs is related to erosion. In middle to late Quaternary arcs, uplift and erosion have not exposed mineralization. In contrast, in the Cretaceous and early Paleogene arcs, erosion has largely removed potentially economic deposits.

The major mineralized magmatic arcs of Southeast Asia include the: (i) Ryukyu in northern Taiwan, (ii) Luzon Central Cordillera, Western Luzon, Cordon, Philippine, Masbate-Negros, Sulu-Zamboanga and Cotobato in the Philippines, (iii) North Sulawesi-Sangihe, Halmahera, Medial Irian Jaya (Central Range-Papuan fold and thrust belt), Sunda-Banda and Central Kalimantan in Indonesia, and (iv) Burman in Myanmar. Secondary arcs in the Philippines, Indonesia and Eastern Malaysia also host gold mineralization, but to a lesser extent than the primary arcs.

The Neogene Kinabalu pluton and satellite intrusions in Sabah, Malaysia occur in a unique setting, in that these bodies do not lie along a defined magmatic arc and lack coeval volcanics.

Porphyry and epithermal mineralization styles predominate, while skarn, carbonate-base metal-gold, sediment-hosted and volcanogenic massive sulfide/exhalative deposits are less abundant.

## TECTONOSTRATIGRAPHIC TERRANES OF MAINLAND SOUTHEAST ASIA

Mainland Southeast Asia consists of several tectonostratigraphic belts, which represent four major crustal blocks or terranes (Fig. 10). From west to east, these are: (i) the Burma Plate, (ii) the Shan-Thai Craton and marginal fold belts of Nam Tha-Sukothai and the Western belt of Peninsular Malaysia, (iii) the Indochina Plate and marginal fold belts of Luang Prabang-Loei-Petchabun, Siem Reap and the Central and Eastern belts of Peninsular Malaysia, and (iv) the South China Plate. The boundaries between these terranes are delineated by major sutures, which are commonly characterized by ophiolitic belts and structural discontinuities.

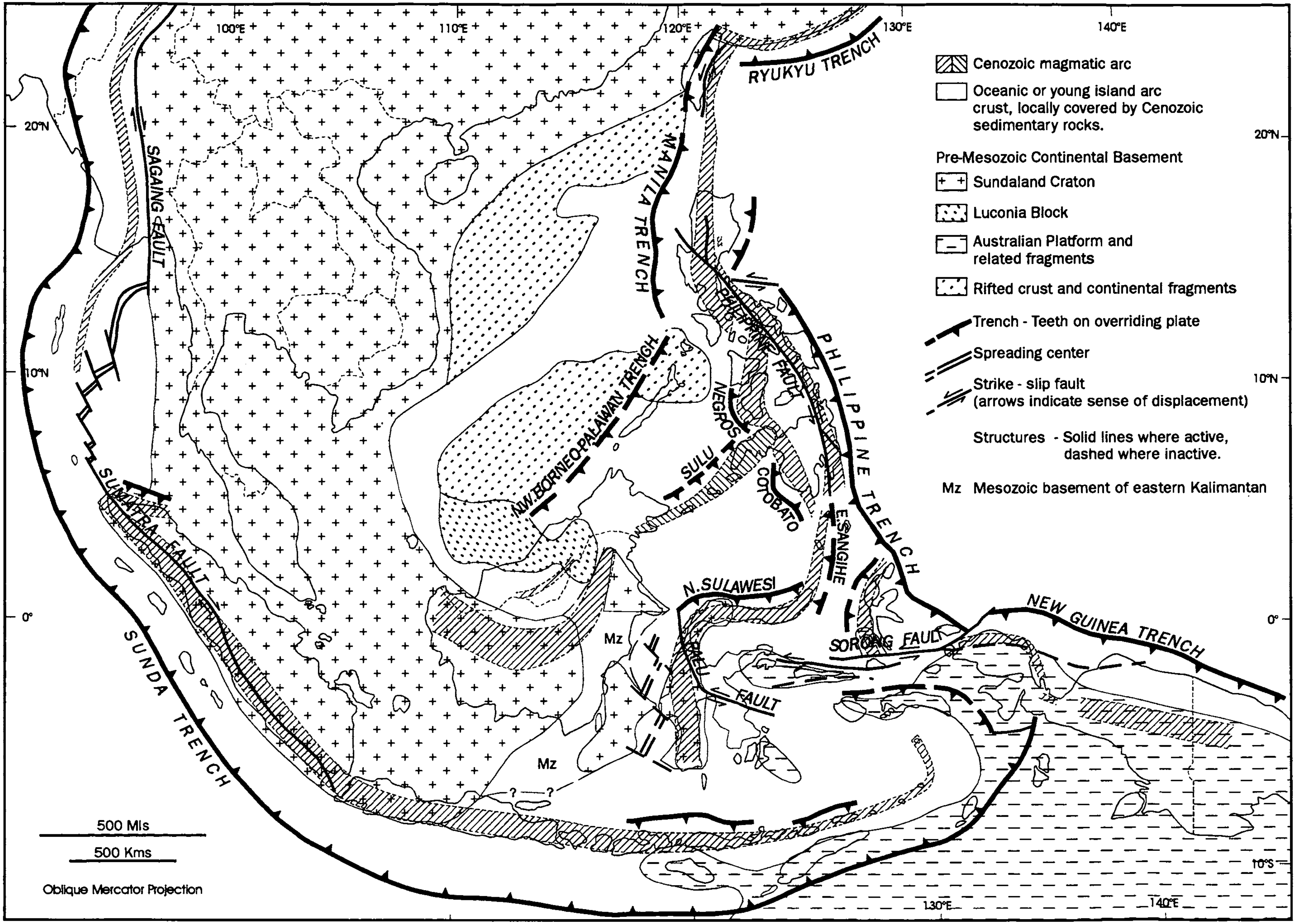


**Figure 4.** Tectonic framework of Southeast Asia, modified after Hamilton (1979), Hutchison (1989), Mitchell and Leach (1991) and Carlile and Mitchell (1994). The distribution of pre-Mesozoic continental basement, Cenozoic magmatic arcs and trench systems are indicated.

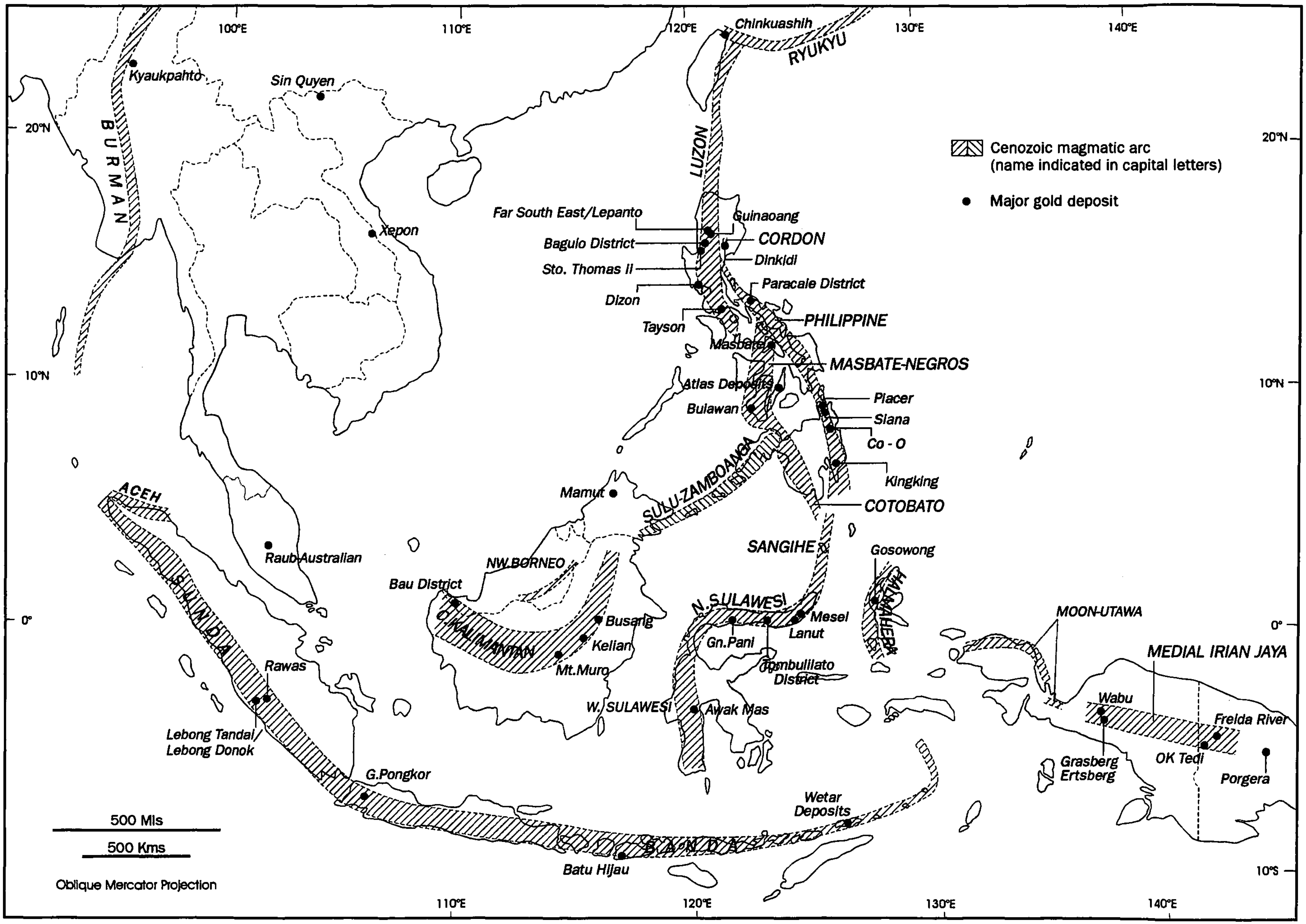


**Figure 5.** Location of the major gold and copper-gold deposits of Southeast Asia. Cenozoic magmatic arcs are modified from Mitchell and Leach (1991) and Carlile and Mitchell (1994).

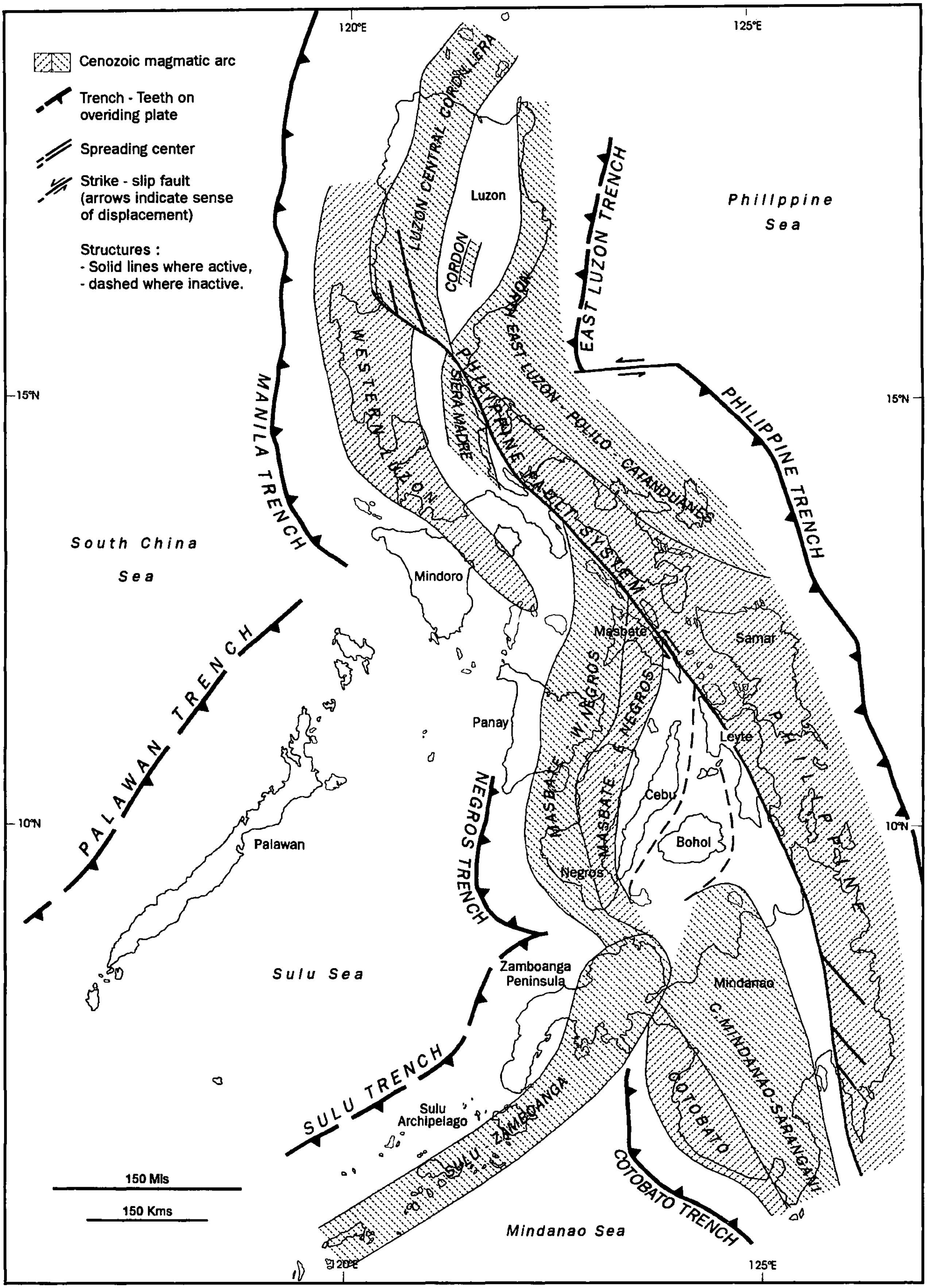


**Figure 6.** Cenozoic magmatic arcs of the Philippines, modified after BMG (1982) and Mitchell and Leach (1992). Magmatic arcs in the Cebu-Bohol region are not well constrained.

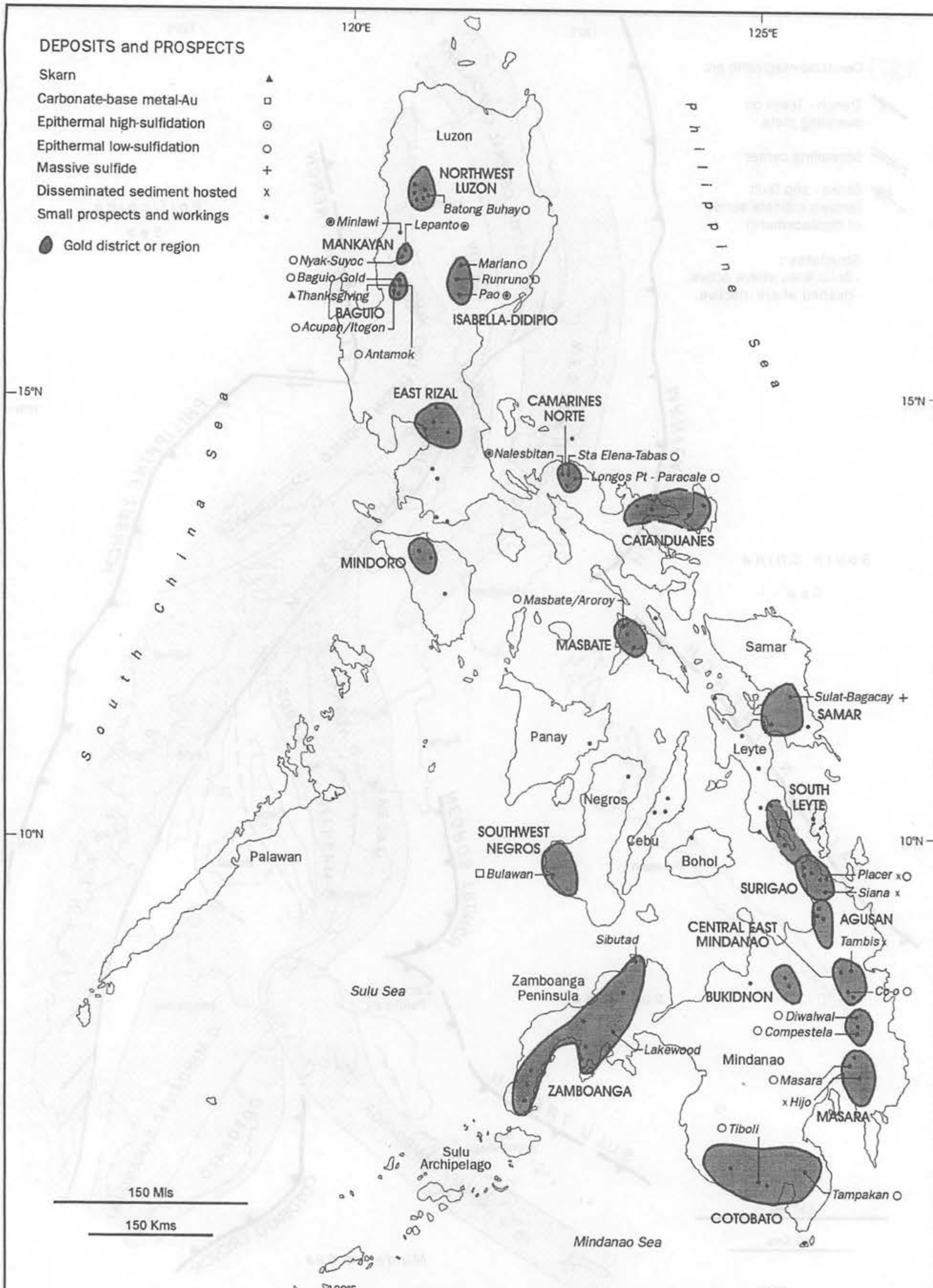


**Figure 7.** Location of the major gold deposits, prospects and districts of the Philippines, compiled after several sources, including BMG (1986), Mitchell and Leach (1991) and UNDP (1992).

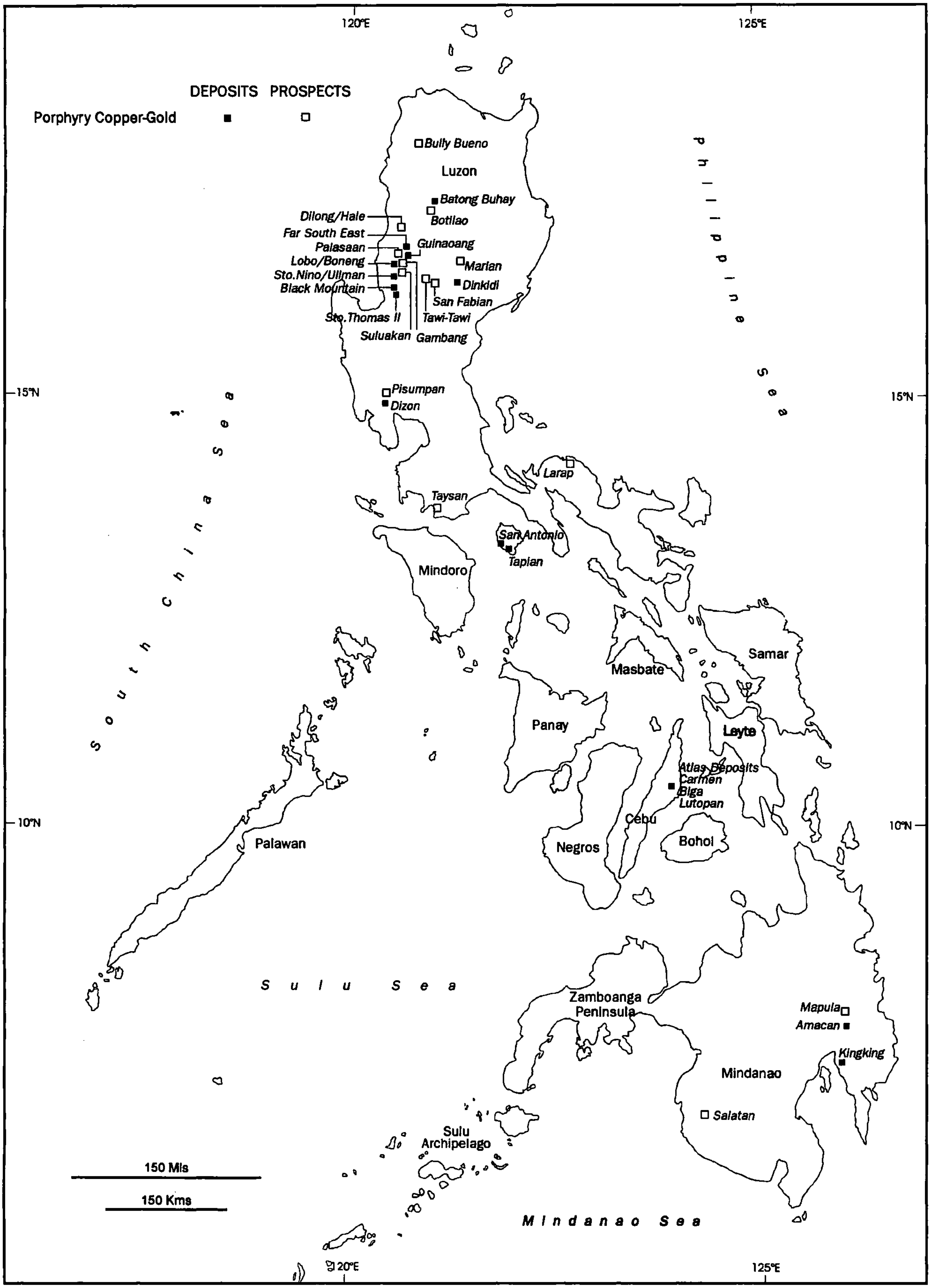


**Figure 8.** Location of the major porphyry copper-gold deposits and prospects of the Philippines, modified after Sillitoe and Gappe (1984) and BMG (1986).

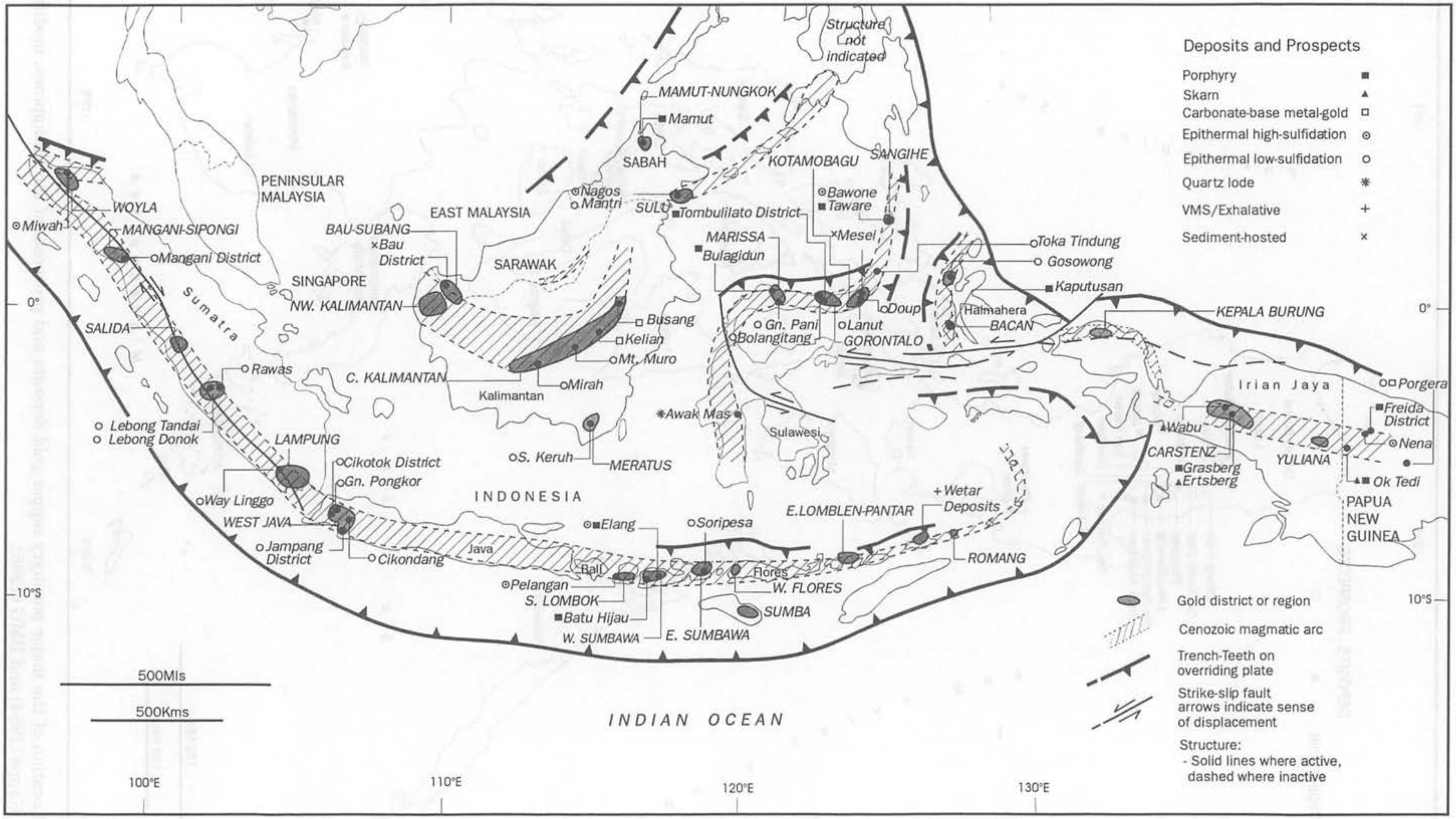


**Figure 9.** Location of the major gold and gold-copper deposits, prospects and districts of Indonesia and East Malaysia, magmatic arcs after Carlile and Mitchell (1994).

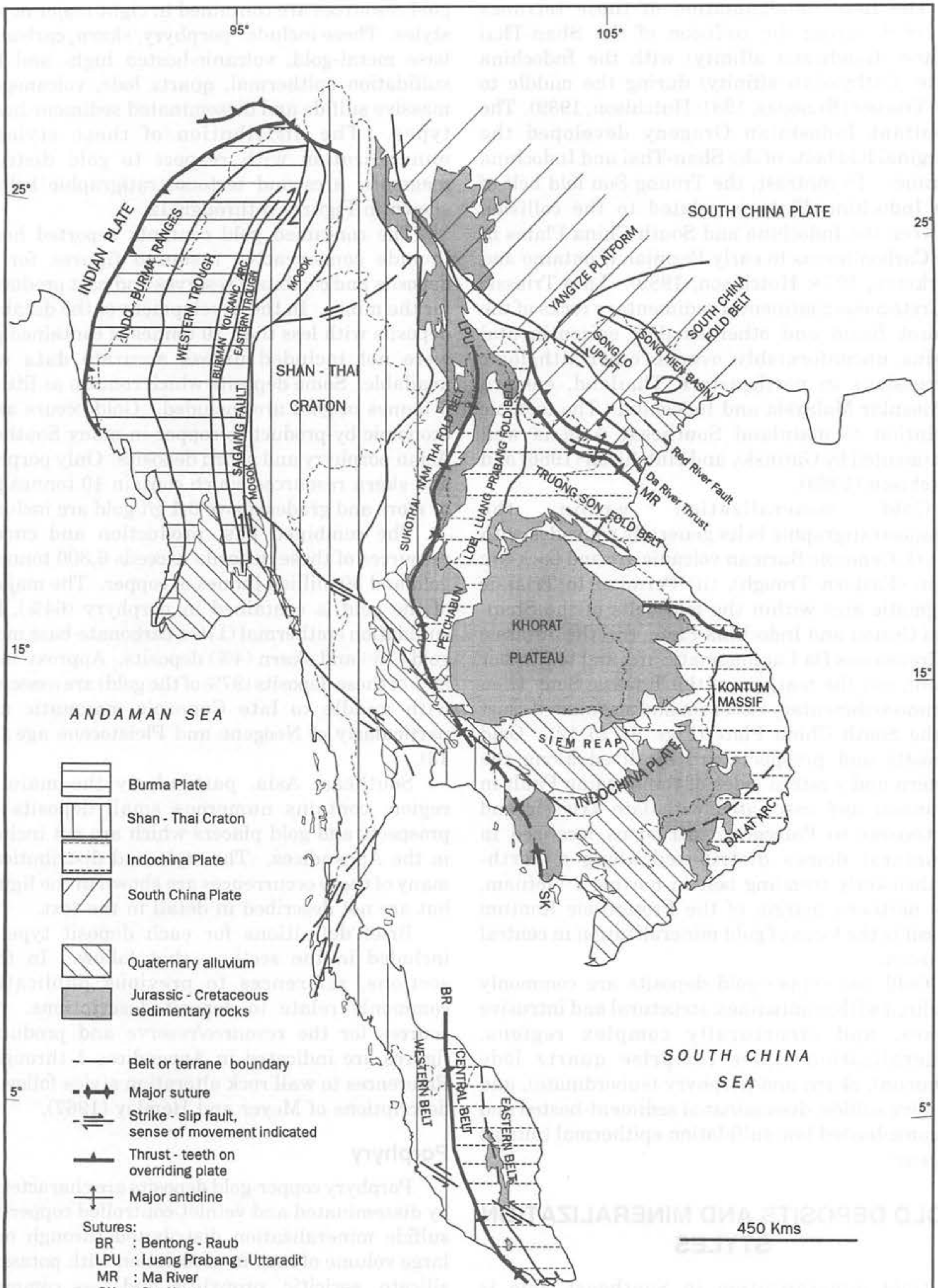


**Figure 10.** Tectonic framework of mainland Southeast Asia, compiled from several sources, including Fontaine and Workman (1978), UNDP (1978), Hutchison (1989), GSV (1991) and GSM (1993).

The final amalgamation of these terranes occurred during the collision of the Shan-Thai Craton (Gondwana affinity) with the Indochina Plate (Cathyasian affinity) during the middle to late Triassic (Bunopas, 1981; Hutchison, 1989). The resultant Indosinian Orogeny developed the marginal fold belts of the Shan-Thai and Indochina terranes. In contrast, the Troung Son fold belt of the Indochina Plate is related to the collision between the Indochina and South China Plates in the Carboniferous to early Permian (Fontaine and Workman, 1978; Hutchison, 1989). Late Triassic to Cretaceous continental sedimentary rocks of the Khorat Basin and other smaller epicontinental basins unconformably overlie older lithologic successions in northeastern Thailand, eastern Peninsular Malaysia and Indochina. The tectonic evolution of mainland Southeast Asia is well documented by Gatinsky and Hutchison (1986) and Hutchison (1989).

Gold mineralization within the tectonostratigraphic belts generally coincides with the: (i) Cenozoic Burman volcanic arc and back-arc basin (Eastern Trough), (ii) Permian to Triassic magmatic arcs within the fold belts of the Shan-Thai Craton and Indochina Plate, (iii) the Jurassic to Cretaceous Da Lat magmatic arc, and to a lesser extent, (iv) the margins of the Triassic Song Hien volcano-sedimentary rift basin and attenuated crust of the South China Plate (Figs. 10 to 12). Gold deposits and prospects are localized along the eastern and western sides of the Sagaing Fault in Myanmar and associated with late Triassic and Cretaceous to Paleogene intrusions localized in structural domes distributed along a north-northeasterly trending belt in northern Vietnam. The northern margin of the Proterozoic Kontum massif is the focus of gold mineralization in central Vietnam.

Gold and copper-gold deposits are commonly localized within anticlines, structural and intrusive domes, and structurally complex regions. Mineralization styles comprise quartz lode (common), skarn and porphyry (subordinate), and massive sulfide, disseminated sediment-hosted and volcanic-hosted low-sulfidation epithermal (minor) systems.

## GOLD DEPOSITS AND MINERALIZATION STYLES

Gold mineralization in Southeast Asia is associated with a wide range of deposit styles. A total of 90 gold and copper-gold deposits are compiled into a database which includes geologic setting, style, and grade-tonnage distributions for the deposits (Appendices 1 through 4). Significant gold resources are contained in eight major deposit styles. These include: porphyry, skarn, carbonate-base metal-gold, volcanic-hosted high- and low-sulfidation epithermal, quartz lode, volcanogenic massive sulfide and disseminated sediment-hosted types. The distribution of these styles of mineralization with respect to gold districts, magmatic arcs and tectonostratigraphic belts is shown in Figures 5 through 12.

The contained gold contents reported herein include conservative resource figures for the deposits and combined reserves and past production for the mines. In the development of the database, deposits with less than 10 tonnes of contained gold were not included unless accurate data were available. Some deposits which contain as little as 6 tonnes of gold are included. Gold occurs as an economic by-product to copper in many Southeast Asian porphyry and skarn deposits. Only porphyry and skarn resources which contain 10 tonnes gold or more and grades above 0.1 g/t gold are included.

The combined past production and current resources of these deposits exceeds 6,800 tonnes of gold and 50 million tonnes of copper. The majority of the gold is contained in porphyry (64%), low-sulfidation epithermal (17%), carbonate-base metal-gold (7%) and skarn (4%) deposits. Approximately 90% of these deposits (97% of the gold) are associated with middle to late Cenozoic magmatic arcs, particularly of Neogene and Pleistocene age (Fig. 13).

Southeast Asia, particularly the mainland region, contains numerous small deposits and prospects and gold placers which are not included in the Appendices. The style and distribution of many of these occurrences are shown in the figures, but are not described in detail in the text.

Brief definitions for each deposit type are included in the sections that follow. In these sections, references to previous publications commonly relate to deposit descriptions. The sources for the resource/reserve and production figures are indicated in Appendices 1 through 3. References to wall rock alteration styles follow the descriptions of Meyer and Hemley (1967).

### Porphyry

Porphyry copper-gold deposits are characterized by disseminated and veinlet-controlled copper-iron sulfide mineralization distributed through out a large volume of rock in association with potassium silicate, sericitic, propylitic and less commonly advanced argillic alteration in porphyritic plutons and in the immediate wall rocks (Lowell and Guilbert, 1970). Porphyry deposits are the product of large volume hydrothermal systems related to small volume intrusions emplaced at shallow crustal

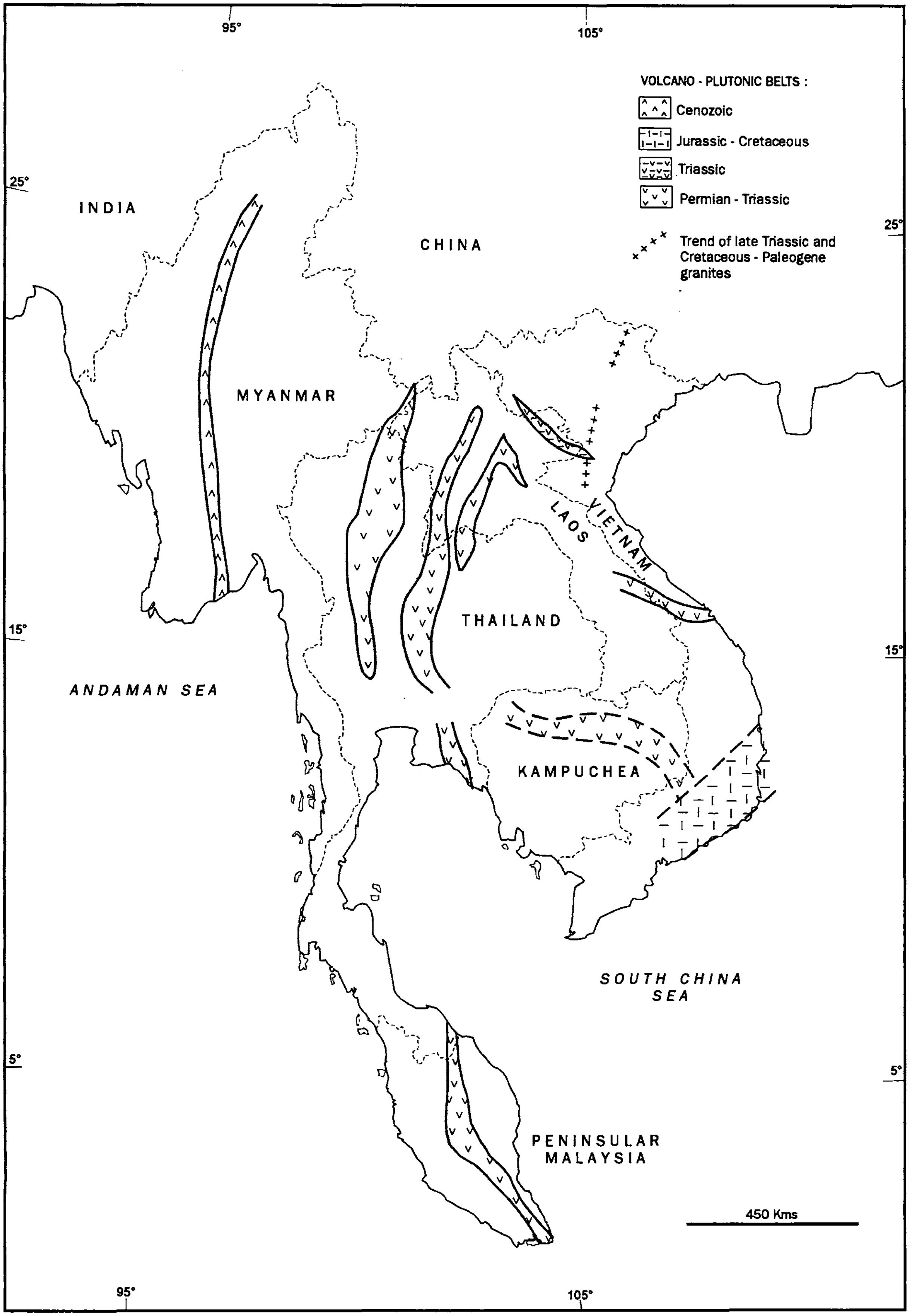


**Figure 11.** Late Paleozoic to Cenozoic volcano-plutonic belts associated with gold and copper mineralization in mainland Southeast Asia, compiled from DMR (1982), Gatinsky and Hutchison (1986), GSV (1991) and GSM (1993).

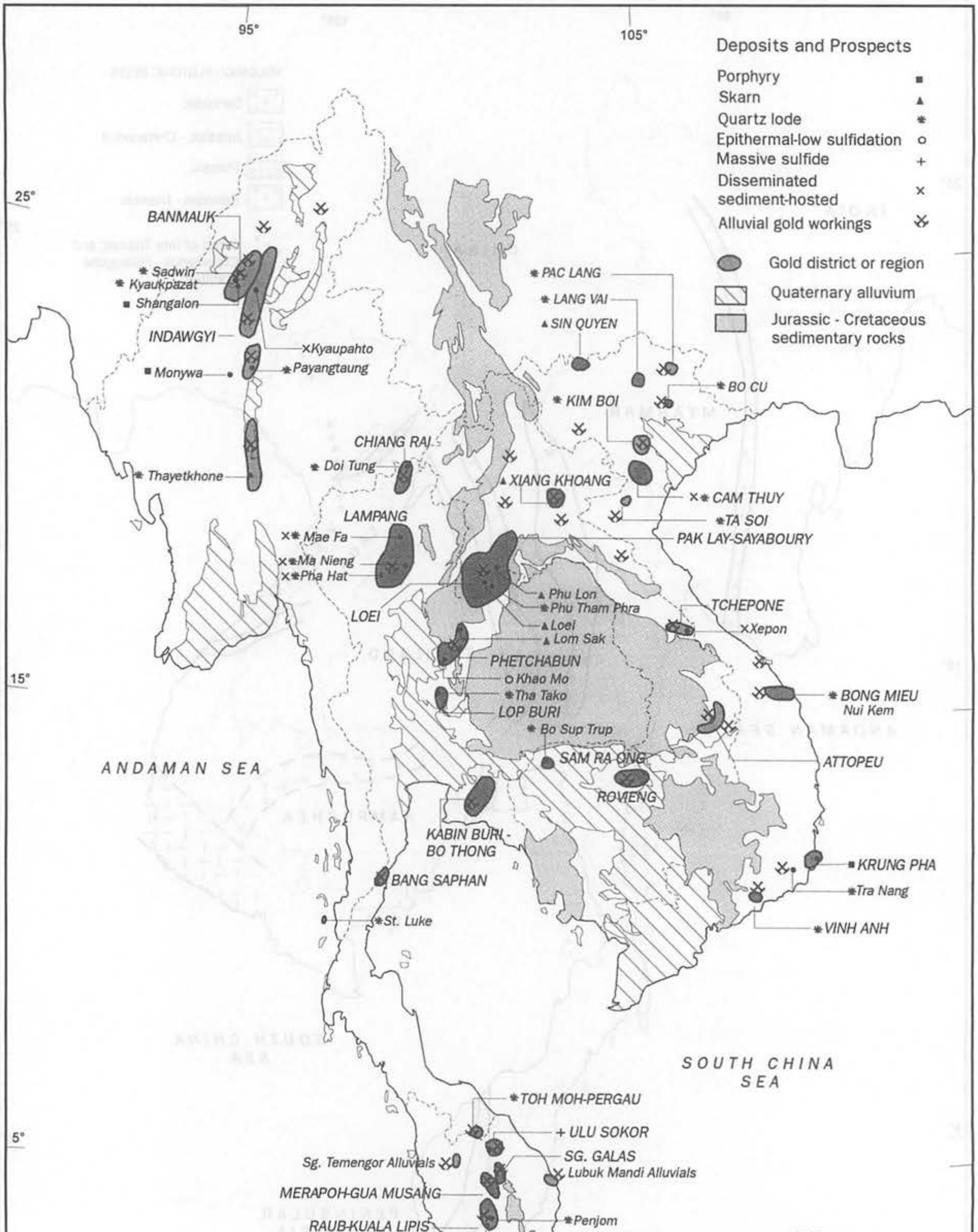


**Figure 12.** Location of major gold deposits, prospects and districts of mainland Southeast Asia, compiled from UNDP (1978b), Shawe (1984), GSM (1988), United Nations (1990a, b and 1993) and Khin Zaw (1994).

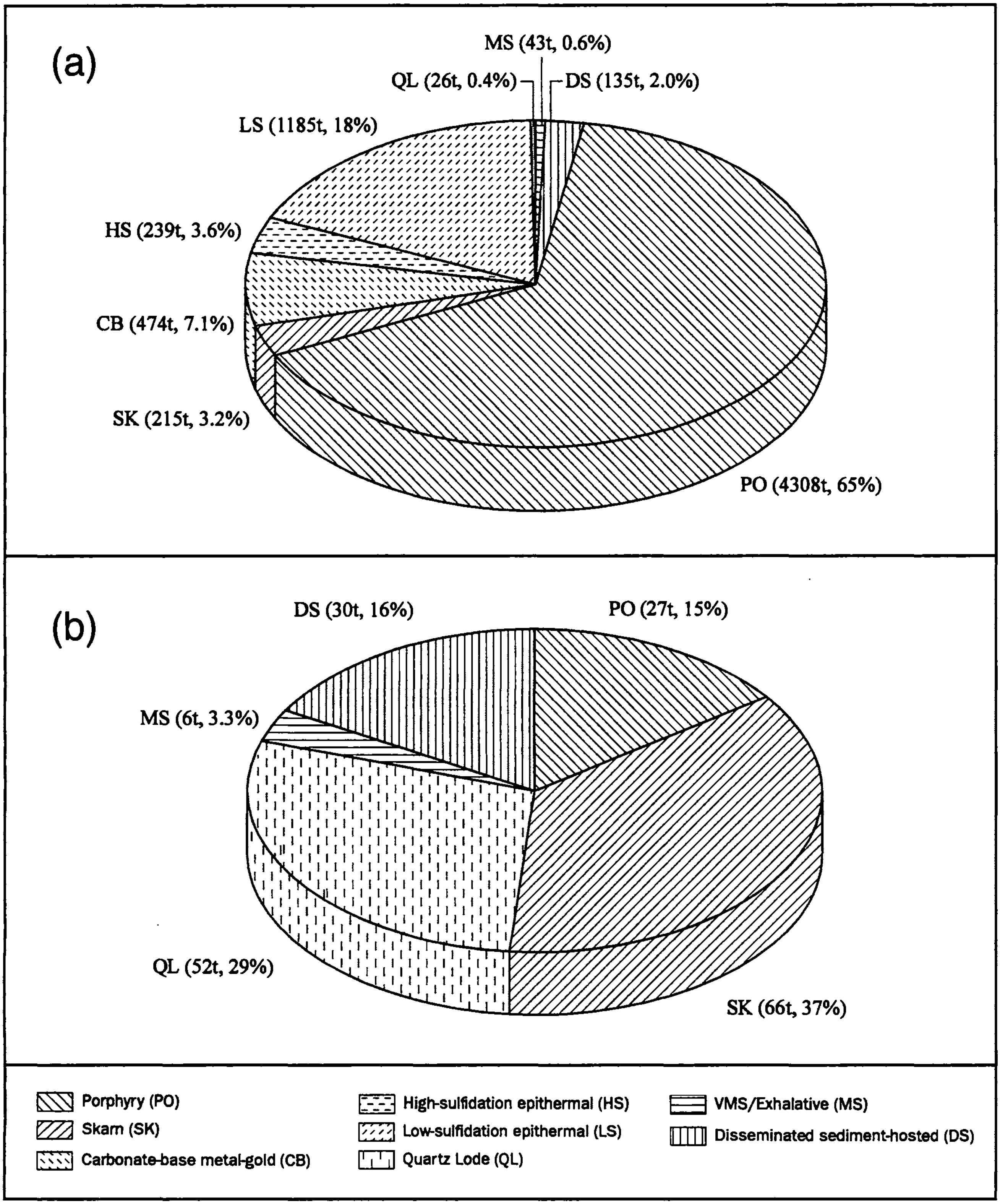


**Figure 13.** Distribution of gold resources (tonnes, including past production) by deposit type for Southeast Asia. (a) Cenozoic magmatic arcs — total of 6,625 t Au contained in 81 deposits. (b) pre-Cenozoic tectonostratigraphic belts — total of 181 t Au contained in 9 deposits.

levels. These deposits contain relatively low copper and gold grades.

All the porphyry deposits compiled are hosted in Cenozoic magmatic arcs with the exception of Mamut in Sabah, which is associated with the Neogene Kinabalu adamellite pluton (Kosaka and Wakita, 1978), and Mengapur in Peninsular Malaysia, which is related to the Permian to Triassic Lepar granodiorite intrusion (Lee *et al.*, 1986).

The Grasberg porphyry copper-gold system in Irian Jaya, Indonesia contains a resource of 4,000 Mt at 0.64 g/t Au (2,560 t) and 0.6% Cu (24 Mt) (van Leeuwen, 1994) and a reserve of 1,600 tonnes of gold. The reserves alone account for approximately 25% of the total gold in Southeast Asia. The deposit is hosted by Pliocene diorite to monzonite stocks (3.3 to 2.7 Ma) and an andesite-diorite diatreme complex (MacDonald and Arnold, 1994). The vertical ore distribution exceeds 1,500 m. It is noteworthy that Grasberg is the only documented gold-rich porphyry deposit of Cenozoic age that overlies pre-Mesozoic continental basement in Southeast Asia (Figs. 4 and 5).

Batu Hijau in Sumbawa contains the second largest gold resource in Indonesia and Southeast Asia (469 t Au). Mineralization is genetically related to two stages of Neogene tonalite intrusions emplaced in diorite and andesitic wall rocks (Meldrum *et al.*, 1994; Irianto and Clark, 1995). A late-mineral diatreme is associated with peripheral gold mineralization 2 km northwest of Batu Hijau. The Tombulilato porphyry systems (140 t Au) in northern Sulawesi are hosted by Miocene volcanic rocks and overlying dacite to rhyolite, which are intruded by quartz diorite stocks (Lowder and Dow, 1978; Perello, 1994). Potassium silicate alteration associated with mineralization indicates a Pliocene age (2.9 to 2.3 Ma; Perello, 1994). Significant porphyry copper-gold systems also occur elsewhere in northern Sulawesi, Halmahera, and Sumbawa.

Porphyry copper-gold deposits are abundant in the calc-alkaline Luzon Central Cordillera and Western Luzon arcs of the Philippines and occur to a lesser extent, in Cebu and in the southeastern Mindanao sector of the Philippine arc. These deposits are typically centered about Neogene to Pleistocene quartz diorite to diorite intrusions hosted by late Cretaceous to Paleogene and early Miocene andesitic volcanic and volcaniclastic sequences (Sillitoe and Gappe, 1984). However, basaltic and dacitic host rocks are present and locally indicate Plio-Pleistocene ages. Intra-mineral intrusions and alteration minerals associated with mineralization in the large gold-rich porphyry systems in the Luzon Central Cordillera and Western Luzon arcs are Plio-Pleistocene in age (Sillitoe and Angeles, 1985; Malihan, 1987; Baluda and Galapan, 1993; Arribas *et al.*, 1995).

Deposits which exceed 100 tonnes of contained gold include Far South East (449 t, Garcia, 1991), Sto. Thomas II (222 t, Sillitoe and Gappe, 1984; Baluda and Galapan, 1993), Lutopan (165 t, 0.027% molybdenum, Cretaceous age, Sillitoe and Gappe, 1984; BMG, 1986), Kingking (164 t, Mitchell and Leach, 1991), Dizon (130 t, Malihan, 1987) and Guinaoang (121 t, Sillitoe and Angeles, 1985). Overprinting of intermediate argillic and sericitic alteration styles on potassium silicate alteration at depth is common and locally associated with enhanced ore grades (e.g. Far South East, Garcia, 1991). Late- to postmineral diatremes and dome complexes are associated with the Far South East, Guinaoang and Dizon deposits (Sillitoe and Gappe, 1984).

Dinkidi (108 t, Haggman, 1994), in the alkaline Cordon arc of northeastern Luzon, is hosted by a monzonite to alkali granite intrusive complex apparently associated with cauldron development.

Monywa, in central Myanmar is hosted by a Pliocene rhyolite porphyry dome emplaced in a sequence of intercalated rhyolitic pyroclastic and siliciclastic rocks (Goosens, 1978). The Monywa porphyry system is considered to be auriferous, but the gold tenor is not well documented.

## Skarn

Skarn is a coarse-grained rock formed from a variety of calc-silicate and iron-oxide minerals through metamorphic recrystallization (regional or contact), bimetasomatic reaction, or infiltration metasomatism of calcareous sedimentary rocks (exoskarn) and the causative intrusion (endoskarn) (Einaudi *et al.*, 1981). The majority of large skarn deposits are directly related to intrusions, both spatially and temporally (Meinert, 1993).

The Ertsberg skarn complex, 2 km southeast of the Grasberg porphyry deposit, includes the Ertsberg, Ertsberg East, Intermediate (IOZ) and Deep Ore Zones (DOZ), Dom, and Big Gossan copper-gold skarn deposits. The majority of the gold and copper resources are hosted in the Erstberg East (IOZ/DOZ) ore body, which contains 103 Mt at 2.09% Cu (2.2 Mt) and 0.77 g/t Au (79 t) in one of the largest copper-bearing magnesian skarns in the world (Rubin, 1994 cited in Mertig *et al.*, 1994). The skarns are hosted within or adjacent to the Pliocene Ertsberg intrusion (3.1 to 2.6 Ma, Mertig *et al.*, 1994). The protolith lithologies consist of a basal dolomitic unit and an upper limestone sequence of early Tertiary age. The recent discovery of the Wabu gold-(copper) skarn in the Hitalipa district, 35 km north of Erstberg, indicates the potential for a minimum gold resource of 62 tonnes at an approximate grade of 3.2–3.5 g/t Au (Potter, personal communication, 1996).

The Sin Quyen copper-gold-rare earth deposit hosted by a Proterozoic gneiss, schist and marble sequence within the Da River mobile belt of northwest Vietnam, has skarn characteristics (GDMG, 1990) and contains a resource of 46 tonnes of gold. The Mengapur porphyry system in Peninsular Malaysia includes a significant skarn component (27 t Au) with anomalous copper, bismuth and molybdenum (Lee *et al.*, 1986; Teoh *et al.*, 1987; Mining Journal, 16 Dec 1994a). The oxidized skarn at Loei (20 t Au), northeastern Thailand (Niugini Mining, 1994) is hosted within a Permian calcareous sequence above a Permo-Triassic intrusion, which indicates porphyry-style mineralization. Sphalerite-rich polymetallic skarn at Thanksgiving, Baguio district, Philippines (Callow, 1967) contains a modest gold content (13 t Au). Small gold- and antimony-rich polymetallic skarn bodies occur proximal to granodiorite stocks in Bau, Sarawak, Malaysia (Wolfenden, 1965; Schuh, 1993).

Several small copper-gold skarn bodies occur in northeastern Thailand. The iron-copper skarns in the Xiang Khoang region of northern Laos may be associated with gold mineralization, as abundant gold placers occur in the region (UNDP, 1990b).

## Carbonate-Base Metal-Gold

Carbonate-base metal-gold deposits are a recently recognized class of intrusion-related, low-sulfidation deposits that contain moderate to large gold resources. This style of deposit develops at intermediate depths and temperatures in an inferred transitional environment between porphyry systems at lower levels and low-sulfidation epithermal quartz-carbonate vein systems at higher levels Leach and Corbett, 1995). At Kelian, one of the best documented deposits of this type, homogenization temperatures for primary fluid inclusions in quartz, carbonate and sphalerite commonly range from 260 to 340°C (van Leeuwen *et al.*, 1990).

The Kelian disseminated gold deposit in eastern Kalimantan, Indonesia (179 t Au; van Leeuwen *et al.*, 1990) the recently discovered Busang deposit (> 250 t Au; Felderhof *et al.*, 1996) and Bulawan in Negros, Philippines (41 t Au; Bobis and Comia, 1987; Philex, 1995) are classified as carbonate-base metal-gold deposits. Recent developments at Busang, have led to the announcement of a potential resource in excess of 900 tonnes of contained gold averaging ~ 3 g/t Au (Felderhof *et al.*, 1996). Another occurrence is represented by the disseminated mineralization at Porgera in Papua New Guinea (Types A, B and E of Richards and Kerrich, 1993).

The geological characteristics of this class of deposits include andesite to dacite intrusions, which are commonly associated with diatreme and dome complexes (Busang and Bulawan), fluidized breccias ("Muddy Breccia" in Kelian) and andesitic to rhyolitic volcanic and volcaniclastic sequences. Kelian and Busang are localized along the eastern margin of the Central Kalimantan magmatic arc adjacent to the middle to late Tertiary Kutei sedimentary basin. Ore is hosted by intrusive and volcanic rocks which have undergone extensive hydrothermal brecciation. Limited radiometric dating at Kelian indicates latest Oligocene to early Miocene ages for andesite intrusions (23 Ma) and sericite alteration (20 Ma) (van Leeuwen *et al.*, 1990). Mineralization at Bulawan is hosted by dacite porphyries and hydrothermal breccias within Miocene andesitic volcanic rocks.

Styles of mineralization include network veining, and breccia and fracture filling by complex carbonate-quartz-pyrite-sphalerite-galena-gold/electrum. Disseminated sulfide mineralization is also common. Deposit gold grades range from 2 to 3 g/t, however, higher grade mineralization occurs locally within zones of Mn and Mg carbonates and base metal sulfide mineralization at depth (van Leeuwen *et al.*, 1990; Leach and Corbett, 1995). Hydrothermal alteration is commonly pervasive and includes "early stage" sericite, quartz ± adularia ± chlorite and "main to late stage" carbonate, sericite and illite ± quartz.

## High-Sulfidation Epithermal

Epithermal systems form at relatively shallow depths (from the surface to 1 to 2 km depth) and low temperatures (commonly 150–300°C), and exhibit variable but characteristic hydrothermal alteration and mineralization styles (Berger and Eimon, 1983; White and Hedenquist, 1995). High-sulfidation, or acid-sulfate, systems are related to hypogene acid fluids generated from the interaction of magmatic and meteoric processes in active volcanic environments (White and Hedenquist, 1995). Characteristic ore minerals include pyrite and enargite-luzonite, while gangue mineralogy is dominated by quartz, kaolinite and alunite. The Lepanto (132 t Au, Mankayan district, Philippines) and Chinkuashih (> 92 t Au, northern Taiwan) enargite-gold deposits are representative of high-sulfidation systems in Southeast Asia.

At Lepanto, leached, "vughy silica" alteration of dacitic wall rocks host enargite-gold branch veins and stratiform lodes localized around the intersection of the steeply dipping Lepanto fault and the shallowly dipping unconformable base of a Pliocene dacitic pyroclastic sequence (Garcia, 1991). The dacitic rocks form part of the Mankayan diatreme-dome complex (Baker, 1992). A clear temporal and spatial relationship exists with the underlying Far Southeast porphyry system. Porphyry-style and enargite mineralization occurred over a 300,000 year interval (~ 1.5 to ~ 1.2 Ma) in the same setting as pre- and postmineral dacite intrusions and pyroclastics which span the periods, 2.2 to 1.8 Ma and 1.2 to 0.9 Ma (Arribas *et al.*, 1995). Low-sulfidation epithermal quartz veins crosscut enargite-gold ore bodies at Lepanto (Nyak veins, Garcia, 1991).

At Chinkuashih, enargite-gold veins, lenses, breccia pipes and stratiform replacement bodies are hosted in Pleistocene subvolcanic dacite intrusions and Miocene calcareous sandstones and carbonaceous shales (Tan, 1991). Up to 60 separate ore bodies have been exploited in the Chinkuashih district throughout its history. Bonanza grades have been reported from many of these deposits, but in more recent years mine grades averaged ~ 5 g/t Au. The majority of the past production was from the 2 km long Penshan-Hsumei vein system in the central portion of the district. Deposits in the district were mined over a vertical extent of 900 m. The deepest portions of the mines are copper-rich, with gold grades increasing towards surface (Tan, 1991). Two major mineralizing events are documented by Wu (1994) and include early copper sulfide and sulfosalt mineralization and a later quartz-gold event.

High-sulfidation systems occur elsewhere in Southeast Asia, however, they currently do not represent significant gold resources. Other occurrences include Nalesbitan in Camarines Norte, Philippines (Sillitoe *et al.*, 1990), Bawone-Binebase(?) in Sangihe, Indonesia (Swift and Alwan, 1990; van Leeuwen, 1994) and Miwah in northern Sumatra, Indonesia (Williamson and Fleming, 1995). Small high-sulfidation systems also occur at Minlawi in northern Luzon, Philippines and Nagos in Sabah, Malaysia (Yan, 1990).

## Low-Sulfidation Epithermal

Low-sulfidation, or adularia-sericite, epithermal systems occur in similar depth and temperature environments as defined for high-sulfidation systems. However, the hydrothermal fluids which generate low-sulfidation gold deposits are near-neutral in pH (Henley and Ellis, 1983; White and Hedenquist, 1995). Classic, banded and brecciated textures and characteristic gangue mineralogy (quartz, illite/sericite, carbonate and adularia) typically characterize bonanza quartz vein systems, exemplified by Hishikari in Japan (Izawa *et al.*, 1990).

Large low-sulfidation vein systems form the Antamok, Acupan and Itogon deposits in the Baguio district, Philippines. Total contained resources (including past production) of these systems is ~ 400 tonnes gold from Antamok and Acupan and 122 tonnes from Itogon. The combined value for Antamok and Acupan reflects combined production figures reported from 1958–1992 (BMG, 1986; Benguet Corp., 1995).

In Acupan, several major quartz-gold vein systems occur adjacent to and within the Pleistocene Balatoc diatreme. These deposits include sheeted veins, stockworks and the high grade "GW" breccia bodies (Cooke and Bloom, 1990). Quartz veins were mined to depths exceeding 700 m. Epithermal veins overprint porphyry-style mineralization in the lower sections of the mine, which establishes a genetic link between these two deposit styles (Cook and Bloom, 1990). The Itogon quartz-gold vein deposit occurs along the eastern periphery of the Balatoc diatreme and is the extension of the Acupan system. The total length of the combined deposits is ~ 4 km. In Antamok, major quartz vein systems and associated stockworks are hosted by andesitic agglomerate and intercalated lava flows (Fernandez *et al.*, 1979). Emplacement of the Antamok vein systems was controlled by dilational fractures developed along regional strike-slip faults. The average global grades of these three deposits are inferred to range from 4 to 6 g/t Au. This range includes past production from high-grade (> 10 g/t Au) lodes.

Gunung Pongkor (103 t Au at 17.1 g/t Au) in western Java, Indonesia is a classic low sulfide bonanza vein system hosted by Miocene andesitic tuffs and breccias, and a subvolcanic andesite intrusion (Basuki *et al.*, 1994). High gold grades are typical of the historic quartz vein lodes of Lebong Tandai (43 t Au at 15.5 g/t Au) and Lebong Donok (41 t Au at 14.3 g/t Au) in Bengkulu, Sumatra. Lebong Tandai is hosted by Miocene andesitic volcanics and Lebong Donok occurs in Miocene carbonaceous shale associated with the brecciated margins of a competent dacite intrusion (Kavalieris, 1988). The recently discovered Gosowong vein in the Halmaheras is high-grade (29 t at 29 g/t Au, Newcrest Mining, 1996). Gold grades in the polyepisodic quartz vein systems at Mt. Muro (47 t Au at 3.4 g/t Au) in Kalimantan are lower in value, which in part reflects dilution by poorly mineralized vein phases (Simmons and Browne, 1990). Low-sulfidation epithermal vein systems commonly lack an obvious link to coeval intrusions in Indonesia.

The Longos lode (38 t Au at 12 g/t Au) in Camarines Norte and the Masara mine (34 t at 8.7 g/t Au) in southeastern Mindanao, Philippines indicate moderate to high grades. Longos is hosted by serpentinized ultramafics along the margin of a trondjhemite body (UNDP, 1987a). The vein systems of Masara occur within andesitic volcanics and volcaniclastics intruded by Pliocene diorite and andesite porphyry intrusions (Mercado *et al.*, 1987a; Mitchell and Leach, 1991).

Vein, stockwork and disseminated styles of mineralization comprise relatively low-grade and moderate tonnage deposits at Placer (65 t Au at ~ 1.6 g/t Au) in northeastern Mindanao, Philippines and Gunung Pani (41 t Au at ~ 1.4 g/t) in northern Sulawesi, Indonesia. Siliceous limonitic fractures and quartz veinlets transect intermediate argillic altered Miocene to Pliocene(?) andesitic pyroclastics, volcaniclastics and hypabyssal intrusions at Placer (Aquino, 1983; UNDP, 1987b). Mineralization at Gunung Pani consists of siliceous limonitic and quartz-adularia lined fractures and mosaic quartz breccias hosted by a pervasive albite-chlorite altered rhyodacitic dome complex of Neogene age (Carlile *et al.*, 1990; Kavalieris *et al.*, 1990).

The Masbate (Aroroy) deposit (62 t Au) consists of sheeted quartz veins, stockworks and breccias hosted in variably silicified Miocene andesite to dacite tuffs and agglomerates (Mitchell and Leach, 1991). Historic production was from underground quartz lodes. Open pit reserves established in 1980 averaged 2.3 g/t Au.

The remaining low-sulfidation epithermal deposits contain less than 30 tonnes of gold and include systems in northern Luzon and eastern Mindanao in the Philippines, and northern Sulawesi, central Kalimantan, southern Sumatra and western Java in Indonesia. Additional prospects are located in the Semporna Peninsula of Sabah, Malaysia, and in the Petchabun region of northeastern Thailand.

## Quartz Lode

This style of mineralization is characterized by structurally-controlled auriferous, polymetallic sulfide-bearing quartz vein systems, which are commonly hosted in variably metamorphosed sedimentary and volcanic wall rocks. Some of the vein deposits and prospects (e.g. those in Peninsular Malaysia) bear similarities to mesothermal lodes emplaced in low- to medium-grade metamorphic terrains (Hodgson, 1993). In contrast, others (e.g. those in Vietnam) indicate hydrothermal alteration styles and fluid inclusion homogenization temperatures characteristic of the deeper levels of a low-sulfidation epithermal environment. However, the classic textures commonly associated with epithermal veins are conspicuously absent. Therefore, a genetic classification of these quartz lode systems would be inaccurate and misleading. In this paper, deposit classification is based on descriptive elements, rather than inferred environment of mineralization.

The historic Raub-Australian mine (30 t Au) in Pahang, Peninsular Malaysia exploited two major lodes, consisting of quartz veins, stockworks and local breccias associated with quartz-calcite replacements and laminations in tightly folded, calcareous graphitic shale of Triassic age (Lee *et al.*, 1986). The Eastern Lode extends over 4.3 km along strike and was mined down to a depth of 355 m. Free gold occurs in quartz where it is associated with arsenopyrite, pyrite, stibnite and scheelite. Gold fineness exceeds 960 (Richardson, 1939 cited in Lee *et al.*, 1986). At Penjom (10 t Au) in the Kuala Lipis district, 40 km to the northeast, quartz veins and stockworks are controlled by dilational fractures along a strike-slip fault corridor (Mining Journal, 16 Dec 1994b). Triassic(?) calcareous shale host rocks are intruded by granitoids in the vicinity of the deposit.

Awak Mas (26 t Au) in central Sulawesi, Indonesia, is characterized by pyritic, quartz-albite-carbonate breccias, veins and stockworks hosted in Cretaceous metasedimentary rocks. The deposit Ag/Au ratio is less than one (van Leeuwen, 1994).

Historic mining activities have been undertaken in the quartz lodes in Toh Moh in southern Thailand, Bong Mieu (Nui Kem) in central Vietnam and Bo Sup Trup in Kampuchea. Several prospects and historic workings in the Mogok metamorphic belt of central Myanmar are centered on structurally-controlled quartz lodes (Goosens, 1978; Khin Zaw, 1994). Small quartz lode systems are common in the Indosinian fold belts of Thailand, Malaysia and Kampuchea.

The polymetallic sulfide-bearing quartz-gold lode prospects of Vietnam commonly are associated with sericite/illite alteration of adjacent Proterozoic to Jurassic metasedimentary, sedimentary and volcanic wall rocks (GDMG, 1990). These vein systems are commonly localized in anticlines, structural domes and along the margin of the Song Hien volcano-sedimentary rift basin. Nguyen (1991) infers lode deposition occurred in both shallow (< 1.5 km) and deeper (1.5 to 3.5 km) environments, on the basis of contrasting fluid inclusion homogenization temperatures, ages of host rock and proximity to granitoids. Homogenization temperatures of primary fluid inclusions in vein quartz indicate means which typically range from 200 to 310°C (Do, 1991). Gold fineness typically ranges from 750 to > 900 (Nguyen, 1991).

## Volcanogenic Massive Sulfide

Volcanogenic, or volcanic-associated, massive sulfide deposits occur in submarine volcanic rocks and may have a close association with at least minor amounts of sedimentary rock. The deposits form during the discharge of hydrothermal fluids through the sea floor and consist of two parts: (i) strata bound massive sulfide and exhalite bodies formed on or immediately beneath the sea floor and (ii) underlying, discordant vein, stringer and disseminated ore hosted in a hydrothermal alteration pipe (Ohmoto and Skinner, 1983; Franklin, 1993). Massive sulfide deposits may contain significant gold resources.

The Wetar deposits (23 t Au) in the eastern Banda Arc of Indonesia represent a submarine exhalative system in a sea floor caldera setting similar to the Kuroko deposits in Japan (Sewell and Wheatley, 1994). Gold-silver mineralization occurs in stratiform barite sand units (exhalite) which are underlain by copper-rich massive pyrite-marcasite zones and quartz-pyrite stockworks hosted in argillic altered felsic volcanic breccias of Miocene age. The majority of the copper is contained in enargite, which is atypical of volcanogenic massive sulfide systems.

Kuroko-type mineralization occurs at the Sulat prospect in Samar, Philippines (BMG, 1986). The auriferous Sulat prospect (20 t Au) contains low-grade copper (0.61%) and is characterized by stratiform lenses of massive, breccia-filling, stockwork and disseminated sulfides. These ore bodies are hosted in pyritic, argillic altered Miocene dacite lavas and pyroclastics, and minor intercalated sedimentary rocks.

Massive sulfide mineralization occurs at Manson's Lode in Ulu Sokor, Kelantan, Peninsular Malaysia. Teoh *et al.* (1987) describe a manto-type polymetallic sulfide zone which is localized within limestone and along limestone-phyllite contacts in a Permian marine sequence. Yeap (1988) classifies Ulu Sokor as a proximal exhalative deposit, related to andesitic to rhyolitic volcanism.

## Disseminated Sediment-Hosted

Disseminated sediment-hosted gold deposits are well documented in the western USA (Berger and Bagby, 1991; Percival *et al.*, 1990) and more recently in the Mesel area of North Sulawesi, Indonesia (Turner *et al.*, 1994; Garwin *et al.*, 1995). The salient characteristics of this deposit style include: i) micron-size gold in arsenical pyrite, ii) Au-As-Sb-Hg-Tl geochemical association and iii) alteration of silty carbonate rock characterised by decalcification, dolomitization, silicification, argillization and the introduction of fine sulfides.

The Mesel deposits in the Ratatotok district of northern Sulawesi, Indonesia include Mesel and the Leon's and Nibong Hill satellite deposits. These deposits contain a combined mineable resource of 62 tonnes of gold at an average grade of 6.5 g/t Au. In Mesel, the overwhelming majority of the ore is hosted in a decalcified, dolomitized and silicified Middle Miocene carbonate sequence adjacent to and beneath a premineral porphyritic andesite laccolithic intrusion (Turner *et al.*, 1994; Garwin *et al.*, 1995). The andesite has undergone illite/smectite-pyrite alteration adjacent to mineralized carbonate and is ore grade locally. In the Lobongan area, to the north of Mesel, quartz-calcite lodes transect variably silicified limestone and karst breccias. Residual quartz-clay eluvial deposits occur throughout the Ratatotok district, marking the erosion of mineralized limestone.

Disseminated gold mineralization occurs at Tai Parit (~ 18 t Au) in the Bau district of Sarawak, Malaysia (Wilford, 1955; Wolfenden, 1965; Cox, 1992; Schuh, 1993). Gold is associated with carbonate and siliciclastic members of the Jurassic Bau Limestone in fault contact with the overlying Cretaceous Pedawan Shale. Pervasive silicification and extensive collapse breccias have developed proximal to the shale/limestone contact along the Tai Parit Fault and adjacent to argillic altered dacite porphyry dikes. Tai Parit marks the general intersection between a north-northeasterly trend of Middle Miocene (13 to 10 Ma; MMAJ, 1985) dacite to granodiorite intrusions with the northeasterly trending Bau anticline. Disseminated gold mineralization is associated with arsenopyrite in silicified shale at Jugan, approximately 10 km along trend, to the northeast.

Portions of the Siana mine (26 t Au) in Surigao, northeastern Mindanao, Philippines consist of disseminated mineralization. Host rocks include limestone breccia, carbonaceous and calcareous mudstone and arkosic sandstone of the Oligocene to Miocene Bacuag Formation (Mercado *et al.*, 1987b; UNDP, 1987b). A Miocene andesite porphyry intrusion adjacent to the deposit is intensely illite-pyrite altered. Massive sulfide mineralization accompanies disseminated styles of mineralization at Siana. Disseminated sulfide mineralization is hosted by silica replacement of limestone and dissolution breccias adjacent to andesite porphyry in the Hijo deposit in southeastern Mindanao (Culala, 1987).

The Xepon deposit in the Tchepone region of Laos includes a "premineral resource" of 30 tonnes of gold hosted in silicified black shales of Paleozoic age (van Leuween, personal communication, 1996). Xepon is tentatively classified as a disseminated, sediment-hosted gold deposit, but porphyry and skarn copper-gold systems and quartz vein mineralization also occur in this region.

The Kyaukpahto deposit (15 t Au) in the Myanmar is hosted by a calcareous arkosic sandstone sequence of probable Eocene age (Ye Myint Swe, 1990). Hydrothermal alteration includes decalcification, silica replacement, sericitic and argillic styles. Gold mineralization is associated with fine-grained pyrite and arsenopyrite in quartz veinlets and as disseminated framboidal grains in silicified and brecciated sandstone.

In northern Thailand, the Permian to Triassic calcareous siliciclastic wall rocks to quartz-stibnite-arsenopyrite and quartz-scheelite lodes are locally silicified and contain disseminated gold mineralization. Disseminated sulfide mineralization is hosted by fault zones within Cambrian limestone in the Cam Thuy district of northern Vietnam.

## Deposit Grade-Tonnage Distribution

The grade-tonnage distribution and total gold-(copper) content of 85 deposits and prospects are illustrated graphically in Figures 14 through 17. Deposits less than one million tonnes in size are not indicated.

The porphyry deposits cluster in the lower-right portions of these diagrams, characterized by very low gold grades (typically < 1 g/t Au) and moderate (10 to 100 Mt) to large (> 100 Mt) deposit sizes (Fig. 15a). The majority of the porphyry deposits form a group about 100 Mt at 0.4g/t Au, with the exception of the gold-rich systems (> 0.9 g/t Au, Grasberg, Far Southeast, Dinkidi and Dizon) and deposits exceeding 300 Mt in size (Grasberg, Batu Hijau, Far Southeast, Sto. Thomas II, Kingking, Guinaoang and the Atlas deposits). The molybdenum-rich porphyry systems (e.g. Atlas deposits and Mengapur) form a distinct cluster of low-grade gold and large-tonnage deposits. Eighteen deposits contain more than 30 tonnes gold and 10 exceed 100 tonnes gold from a total of 37 deposits. Skarn deposits contain higher gold grades (typically 0.5 to 3 g/t Au) in relatively smaller deposits. Two of the seven deposits compiled, Ertsberg East (IOZ/DOZ) and Sin Quyen, contain in excess of 30 tonnes gold. These deposits are close to 100 million tonnes in size.

Copper grades of 0.3 to 0.6% characterize the porphyry deposits, with the exception of Grasberg (1.30% Cu in reserve), Sungai Mak (0.76% Cu), Kayubulan (0.76%) and Far Southeast (0.73 % Cu) (Fig. 15b). A positive correlation exists between copper grade and deposit size, particularly for those deposits exceeding 50 million tonnes. Ten porphyry deposits exceed one million tonnes copper, with Batu Hijau containing 5.5 million tonnes and Grasberg including 14.5 million tonnes in reserve. Copper grades of 1 to 4% characterize those skarn deposits which contain significant copper. Only

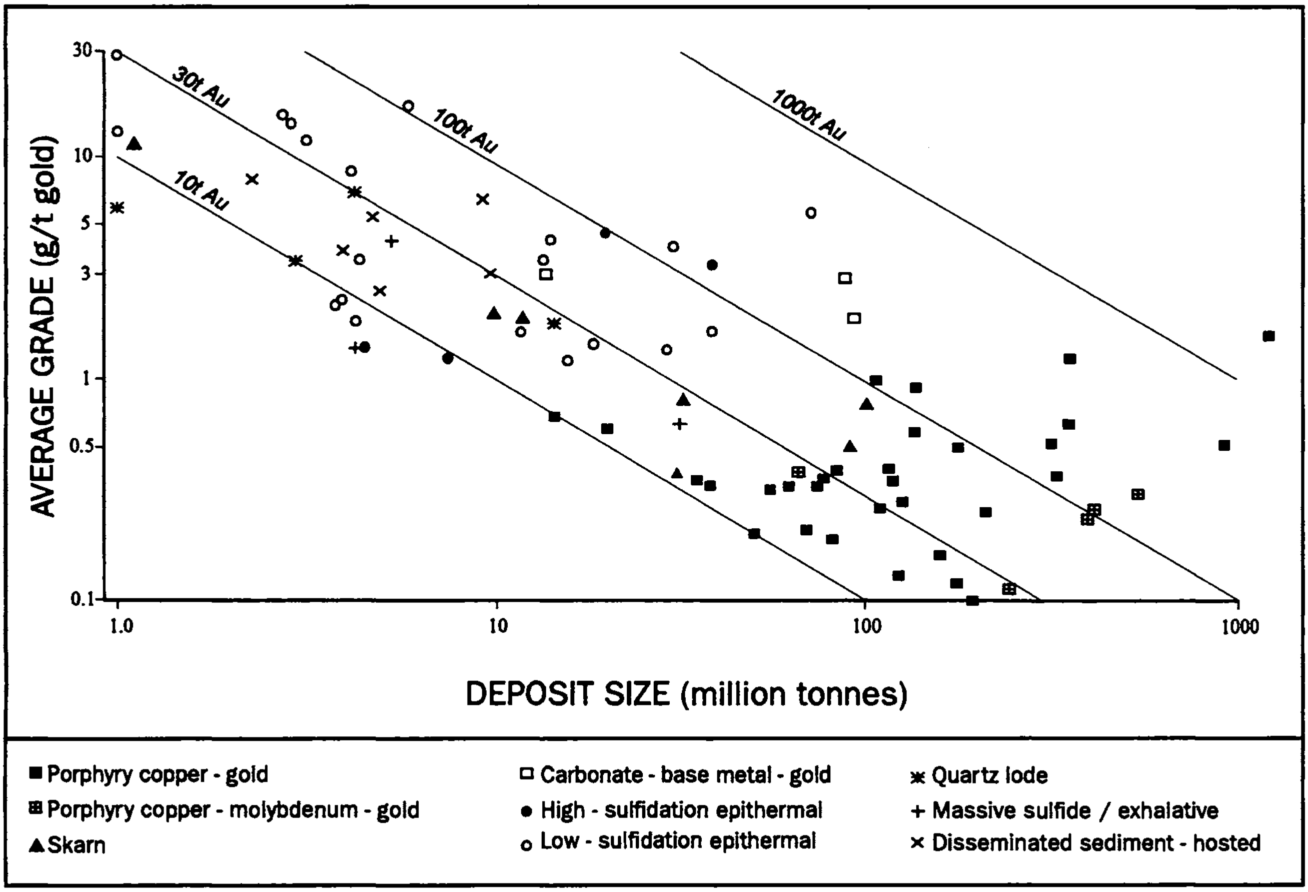


**Figure 14.** Gold grade and size characteristics for gold and copper-gold deposits of Southeast Asia by deposit type, compiled from data tabulated in Appendices 1–4. Eighty-five deposits, those < 1.0 million tonnes in size are not indicated.

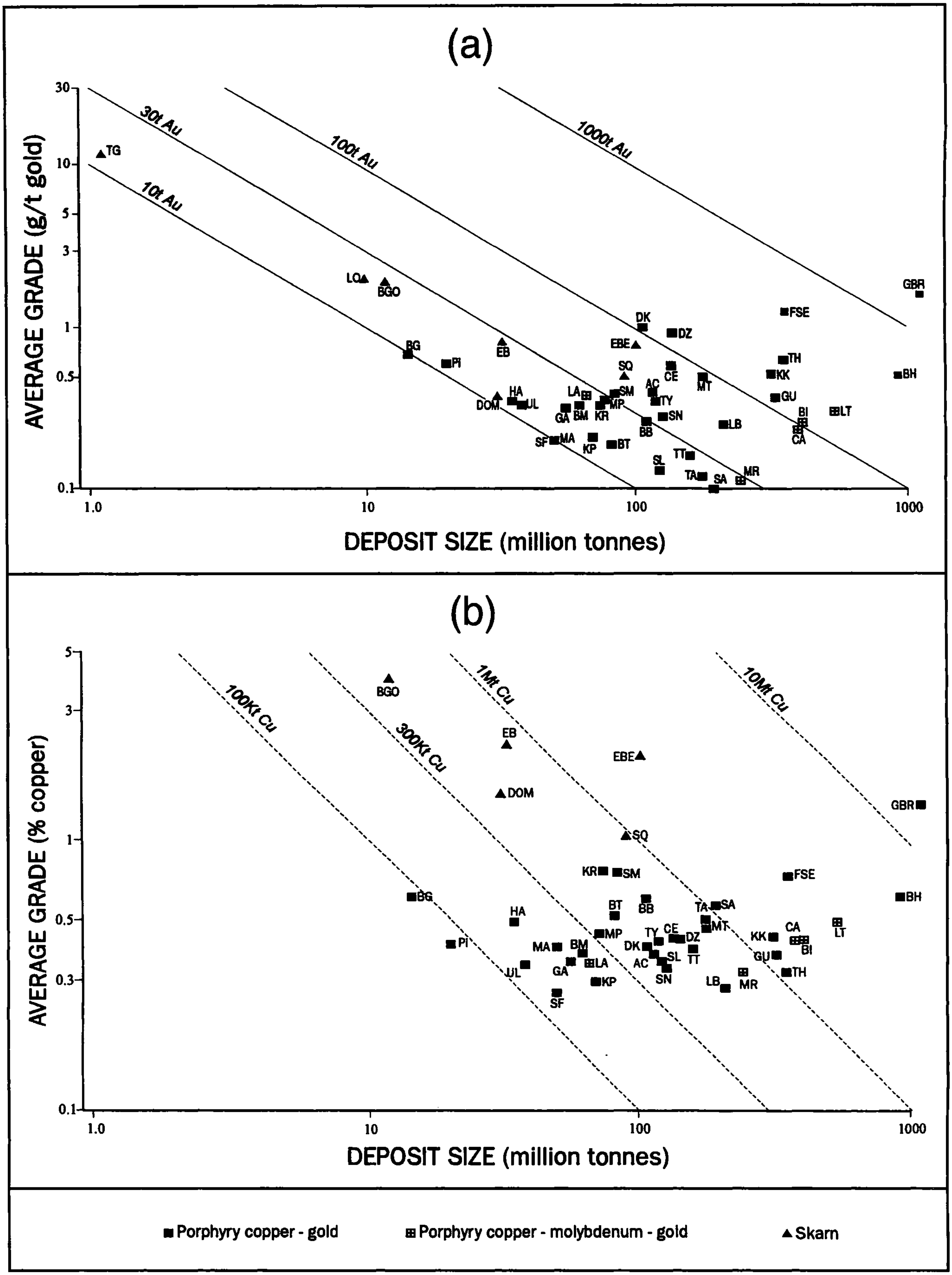


**Figure 15.** Grade and size characteristics for porphyry and skarn deposits. (a) gold, (b) copper.

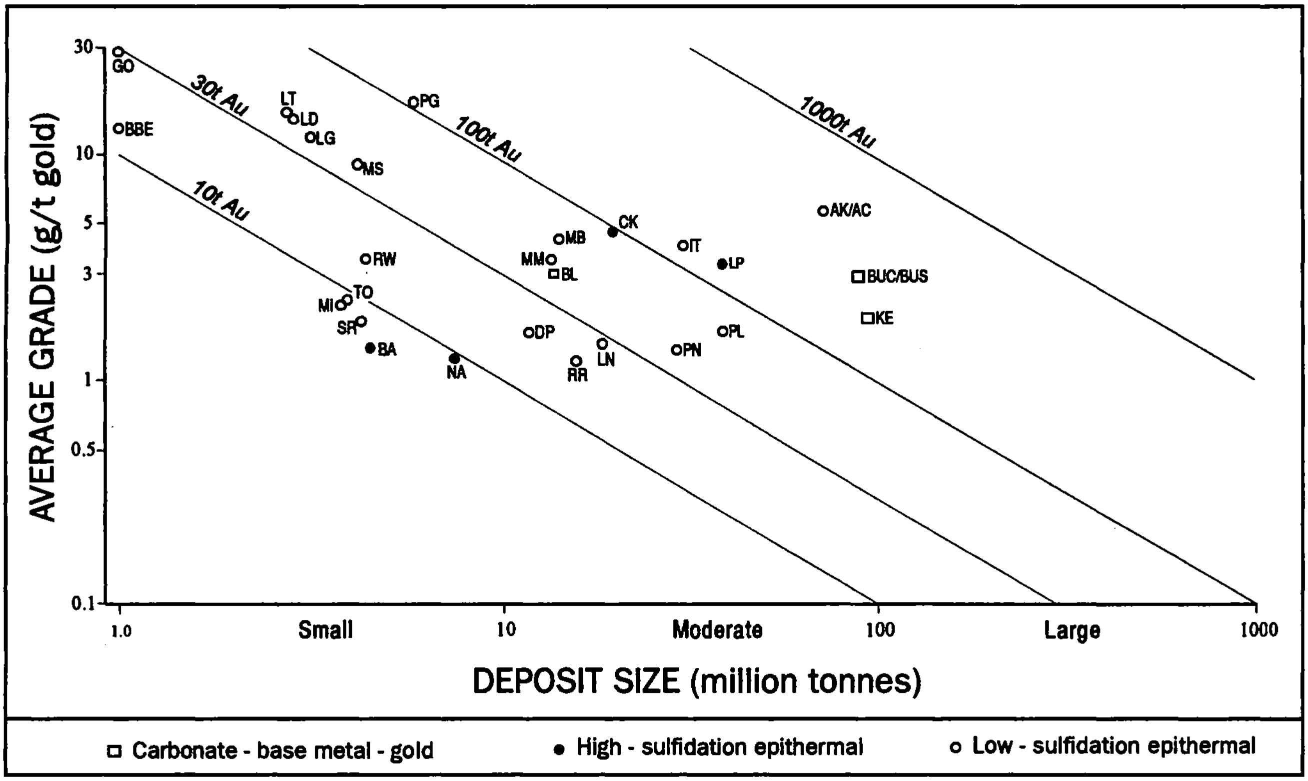


**Figure 16.** Gold grade and size characteristics for epithermal and carbonate-base metal-gold deposits. Combined resources are plotted for Acupan/Antamok and the Busang central/southeastern zones.

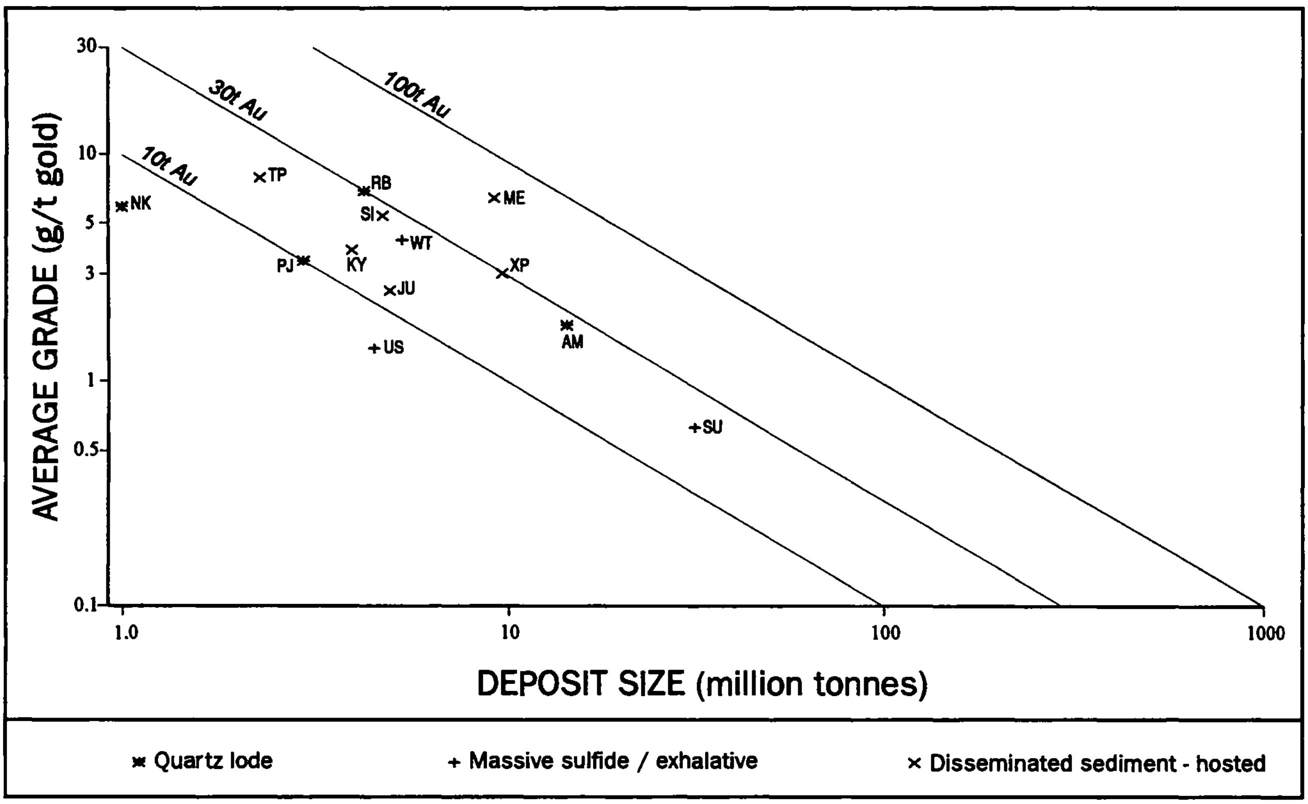


**Figure 17.** Gold grade and size characteristics for quartz lode, massive sulfide and disseminated sediment-hosted deposits.

the Ertsberg East (IOZ/DOZ) skarn contains more than one million tonnes copper.

Carbonate-base metal-gold deposits are low to moderate in gold grade (2 to 3 g/t Au) and moderate in size. All three of the deposits contain more than 30 tonnes gold, with two exceeding 100 tonnes gold (Fig. 16). These two deposits, Busang and Kelian, are nearly 100 million tonnes in size. The Busang figure represents measured and indicated resources only and continues to grow with additional exploration.

The four high-sulfidation epithermal systems compiled range from low to moderate in grade (~ 1 to 5 g/t Au) and small to moderate in size (Fig. 16). Two of these deposits, Lepanto and Chinkuashih, contain approximately 100 tonnes of gold each. Low-sulfidation epithermal deposits define three major groups, including: (i) high-grade (> 10 g/t Au) and small tonnage (< 10 Mt) quartz vein lodes (e.g. Gunung Pongkor and Gosowong), (ii) low- to moderate-grade (1.5 to 6 g/t Au) and moderate sized vein and stockwork deposits (e.g. Antamok, Acupan, Mount Muro, Placer and Gunung Pani), and (iii) low- to moderate-grade (1.5 to 3 g/t Au) and small vein stockwork systems (e.g. Rawas and Toka Tindung). Twelve of the 21 low-sulfidation deposits contain more than 30 tonnes gold and four exceed 100 tonnes gold, Antamok, Acupan, Itogon and Gunung Pongkor.

Quartz lode deposits are typically moderate in grade (3.4 g/t Au, Penjom to ~ 7 g/t Au, Raub-Australian) and small in size, with the exception of Awak Mas in central Sulawesi, which exhibits a lower grade and larger tonnage than the other deposits (Fig. 17). The largest of the four deposits plotted, Raub-Australian, contains 30 tonnes gold. The three volcanogenic massive sulfide and exhalative deposits compiled indicate low to moderate grades (0.6 g/t Au, Sulat to 4.2 g/t Au, Wetar) and small to moderate sizes. All of these deposits contain less than 30 tonnes gold. Disseminated sediment-hosted deposits indicate moderate grades (3 to 8 g/t Au) and small resource sizes. Two of the six deposits, Mesel and Xepon, include 30 tonnes of gold or more.

## CONCLUSIONS

Gold mineralization in Southeast Asia is spatially and temporally related to intrusions and volcanic centers. The overwhelming majority of gold and gold-copper deposits are developed in short sectors of middle Tertiary to Pleistocene magmatic arcs in Indonesia, Philippines, Taiwan and Myanmar. Mineralization within the Indosinian fold belts of mainland Southeast Asia is commonly localized within anticlines and structurally complex regions, which are distributed along Permo-Triassic volcano-plutonic arcs. Other prospective geologic settings are suture zones, major strike-slip faults, structural and intrusive domes and the margins of volcano-sedimentary rift basins.

Porphyry copper-gold deposits are typically related to Neogene calc-alkaline diorite, quartz diorite and minor tonalite intrusions emplaced at shallow depths into andesitic volcanic and volcaniclastic sequences which typically overlie basement of oceanic crust. Intra- and postmineral intrusions are common in the Philippine and Indonesian porphyry systems. Late-mineral dacitic diatreme and dome complexes characterize a number of the Philippine deposits.

Skarns typically occur in calcareous rocks proximal to porphyry systems. Skarns at Ertsberg in Indonesia, Mengapur in Peninsular Malaysia and smaller bodies in northeastern Thailand and Bau, Sarawak, Malaysia were developed in host rocks deposited in continental settings. The lack of thick calcareous rock sequences overlying oceanic crust in the Philippines and the eastern portion of Indonesia reduces the possibility for the development of large economic skarn deposits in these regions.

Carbonate-base metal-gold deposits occur in the lower levels of low-sulfidation epithermal systems and may provide a genetic link to porphyry-style mineralization at depth. However, this relationship requires further study.

High-sulfidation epithermal systems are associated with coeval, hypabyssal dacite intrusions and local diatreme complexes. Low-sulfidation epithermal vein, stockwork and minor disseminated deposits are typically hosted in andesitic volcanics and volcaniclastic sequences within or adjacent to volcanic centers, which developed above oceanic and continental basement. Low-sulfidation epithermal systems commonly lack an obvious link to coeval intrusions. However, at Acupan in the Baguio district, Philippines, a connection to underlying porphyry-style mineralization has been recognized (Cooke and Bloom, 1990).

Quartz lodes are typically structurally-controlled and hosted by late Paleozoic to Triassic metasedimentary and sedimentary rocks in the Indosinian fold belts of Malaysia, Thailand and Kampuchea, and in a variety of geologic settings in Vietnam. No genetic implications constrain this deposit style, as the quartz lodes indicate characteristics of both mesothermal and epithermal environments.

Volcanogenic massive sulfide and exhalative deposits form in sea floor extensional environments. The presence of abundant enargite at Wetar (Sewell and Wheatley, 1994) is atypical and may indicate a link to high-sulfidation epithermal-style mineralization (Carlile and Mitchell, 1994).

Disseminated sediment-hosted deposits occur in calcareous rock sequences deposited in both continental and island arc settings. The Mesel deposits in northern Sulawesi, Indonesia lack an obvious link to a causative intrusion. In contrast, Tai Parit (Bau) replacement-style mineralization in western Sarawak, Malaysia occurs in close proximity to intrusions and skarn and porphyry-style mineralization.

## ACKNOWLEDGEMENTS

This study benefits from a comprehensive regional database compiled by Newmont Southeast Asia geoscientists during the past three years. Steve Turner initiated this compilation in late 1993 and was assisted by Andrew Mitchell, Michael Thomsen, Sam Adams, Romy Aquino and many other Newmont geologists. Gil Alapan was a great help in adding to the Philippine deposit database. Peter Mitchell assisted in the structuring of the text. Mohammed Irsam and Noviandi Chaniago drafted the figures. Nita Kurnitasari prepared the tables and graphs. I thank Newmont Mining Corporation for permission to present this paper.

## REFERENCES

AQUINO, R.S., 1983. Geology and gold mineralization of Manila Mining Corporation's Placer Project area, Surigao del Norte. *Philippine Geol. 37(2)*, 6–19.

ARRIBAS, A., JR., HEDENQUIST, J.W., ITAYA, T., OKADA, T., CONCEPCION, R.A. AND GARCIA, J.S., JR., 1995. Contemporaneous formation of adjacent porphyry and epithermal Cu-Au deposits over 300 ka in northern Luzon, Philippines. *Geology, 23(4)*, 337–340

AURORA MINING, 27 May 1996. Quarterly Report to the Australian Stock Exchange.

BAKER, E.M., 1992. The Mankayan diatreme complex and its relationship to copper-gold mineralization, Northern Luzon, Philippines. *In:* Randol at Minexpo 1992, Proceedings from five workshops, plus a guidebook to mines in Northern Sonora, Mexico, Las Vegas, Nevada, 17–18 October 1992, 69–74.

BALUDA, B. AND GALAPAN, J., 1993. Ore reserve, production history and geologic characteristics of the Sto. Thomas II copper-gold mine. *In:* Geology and Mineral Resources Symposium, Baguio District, December 1993, 10p.

BASUKI, A., ADITYA SUMANAGARA, D. AND SINAMBELA, D., 1994. The Gunung Pongkor gold-silver deposit, West Java, Indonesia. *In:* van Leeuwen, T.M., Hedenquist, J.W., James, L.P. and Dow, J.A.S. (Eds.), Mineral deposits of Indonesia — Discoveries of the Past 25 Years. *J. Geochem. Explor., 50*, 371–392.

BAXTER, J.L., DZUNG, D.H. AND HEWSON, N.G., 1991. The structural controls on gold mineralization at Bong Mieu, Quang Nam-Da Nang Province Central Vietnam. *In:* Second Conference on Geology of Indochina, Hanoi, 261–268.

BENQUET CORP., 1994. 1994 Annual Report, Benquet Corporation.

BENQUET CORP., 1995. Benquet Gold Operations-Information Brochure.

BERGER, B.R. AND EIMON, P., 1983. Conceptual models of epithermal precious metal deposits. *In:* Shanks, W.C., (Ed.), *Cameron Volume on Unconventional Mineral Deposits.* Society of Mining Engineers of AIME, 191–205.

BERGER, B.R. AND BAGBY, W.C., 1991. The geology and origin of Carlin-type gold deposits. *In:* Foster, R.P. (Ed.), *Gold Metallogeny and Exploration.* Blackie, Glasgow and London, 210–248.

BMG, 1982. *Geology and Mineral Resources of the Philippines, Volume 1 (Geology)*, Bureau of Mines and Geo-Sciences Ministry of Natural Resources, 406p.

BMG, 1986. *Geology and Mineral Resources of the Philippines, Volume 2 (Mineral Resources)*, Bureau of Mines and Geo-Sciences Ministry of Natural Resources, 446p.

BOBIS, R.E. AND COMIA, G.M., 1987. Geologic setting and alteration-mineralization characteristics of the Vista Alegre gold zone, Hinoba-an, Negros, Philippines. *In:* Gold 1987 in the Philippine Setting, Proc. Vol. I, 27p. Philippine Institute of Mining, Metallurgy and Geology, Manila.

BUNOPAS, S., 1981. Paleogeographic history of western Thailand and adjacent parts of Southeast Asia: A plate tectonics interpretation. Geological Survey Paper Special Issue, 5. Department of Mineral Resources of Thailand, Bangkok.

CALLOW, K.J., 1967. The Geology of the Thanksgiving mine, Baguio District, Mountain Province, Philippines. *Econ. Geol. 62*, 472–481.

CARLILE, J.C. AND MITCHELL, A.H.G., 1994. Magmatic arcs and associated gold and copper mineralization in Indonesia. *In:* van Leeuwen, T.M., Hedenquist, J.W., James, L.P. and Dow, J.A.S. (Eds.), Mineral Deposits in Indonesia — Discoveries of the Past 25 Years. *J. Geochem. Explor., 50*, 91–142.

CARLILE, J., DIGDOWIROGO, S. AND DARIUS, K., 1990. Geologic setting, characteristics and regional exploration for gold in the volcanic arcs of North Sulawesi, Indonesia. *In:* Hedenquist, J.W., White, N.C. and Siddeley, G. (Eds.), Epithermal Gold Mineralization of the Circum-Pacific: Geology, Geochemistry, Origin and Exploration, *I.J. Geochem. Explor., 35*, 105–140.

COOKE, D.R. AND BLOOM, M.S., 1990. Epithermal and subjacent porphyry mineralization, Acupan, Baguio District, Philippines: a fluid-inclusion and paragenetic study. *In:* Hedenquist, J.W., White, N.C. and Siddeley, G. (Eds.), Epithermal gold mineralization of the circum-pacific, Vol. I: 297–340.

COX, R., 1992. Consultant economic geologist's final technical evaluation report, United Nations Project MAL/88/012. Unpublished Report, United Nations Department of Economic and Social Development, 50p.

CULALA, L.L., JR., 1987. The exploration and geology of the Hijo gold project. *In:* Gold 1987 in the Philippine Setting, Proc. 1, 42p. Philippine Institute of Mining, Metallurgy and Geology, Manila.

DO HAI DUNG, 1991. Fluid inclusions from the gold mines and deposits of Vietnam. *In:* Proceedings of the Southeast Asia Gold Symposium, Ho Chi Minh City, 26–29.

EINAUDI, M.T., MEINERT, L.D., AND NEWBERRY, R.J., 1981. Skarn deposits: Economic Geology, 75th Anniversary Volume, 317–391.

FELDERHOF, J.B., DE GUZMAN, M.T., PUSPOS, C.M. AND NASSEY, J.M., 1996. Mineralization in a maar diatreme-dome complex: Busang gold deposit, East Kalimantan, Indonesia. Paper presented at the Annual Meeting of the Prospectors and Developers Association of Canada, Toronto, Ontario, March 1996, 11p.

FERNANDEZ, H.E., DAMASCO, F.V. AND SANGALAG, L.A., 1979. Gold ore shoot development in the Antamok mines, Philippines, *Econ. Geol. 74*, 606–627.

FONTAINE, H. AND WORKMAN, D.R., 1978. Review of the geology and mineral resource of Kampuchea, Laos and Vietnam. *In:* Third Conference on geology and mineral resource of Southeast Asia, Bangkok, Thailand, 541–603.

FRANKLIN, J.M., 1993. Volcanic-associated massive sulphide deposits. *In:* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I. and Duke, J.M. (Eds.), *Mineral Deposit Modeling*, 315–334.

FREEPORT-MCMORAN MINING, 1994. 1994 Annual Report, Freeport-McMoran Copper-Gold Company.

GARCIA, J.S., JR., 1991. Geology and mineralization characteristics of the Mankayan mineral district, Benquet, Philippines. *In:* Matsuhisa, Y., Aoki, M. and Hedenquist, J.W. (Eds.), High-temperature Acid Fluids and Associated Alteration and Mineralization. Third Symposium on Deep-Crust Fluids. *Geological Survey of Japan Report No. 277*, 17–25.

GARWIN, S.L., HENDRI, D. AND LAURICELLA, P.F., 1995. The geology of the Mesel sediment-hosted gold deposit, North Sulawesi, Indonesia. *In:* Mauk, J.L. and St. George, J.D. (Eds.), *Proceedings of the 1995 Pacrim Congress, Auckland, New Zealand*, 19–22 November 1995, 221–226.

GATINSKY, Y.G. AND HUTCHISON, C.S., 1986. Cathyasia, Gondwanaland, and the Paleotethys in the evolution of continental Southeast Asia. *In:* GEOSEA V Proceedings Vol. II, *Geol. Soc. Malaysia Bulletin 20*, 179–199.

GDMG, 1990. *Geology and Mineral Resources of Vietnam, Volume 1.* General Department of Mines and Geology Socialist Republic of Vietnam, Hanoi, 182p.

GEORGE CROSS NEWSLETTER, 18 April 1996. Busang Reserve Increased, No. 76 (1996).

GOLDFIELDS, 1996. Gold 1995. Goldfields Mineral Services Ltd., 64p.

GOOSSENS, P.J., 1978. The metallogenic provinces of Burma, their definitions, geologic relationships and extensions into China, India and Thailand. *In:* Proceedings of the third regional conference on geology and mineral resources of Southeast Asia (Ed. Prinya Nutalaya), Asian Institute of Technology, Bangkok, 493–536.

GSM, 1988. Mineral distribution map of Peninsular Malaysia, 1:500,000 scale (two sheets). Geological Survey of Malaysia.

GSM, 1993. Annual Report, Geological Survey of Malaysia, 144p.

GSV, 1991. Geology of Cambodia, Laos and Vietnam. Explanatory Notes to 1:1,000,000 geological map (6 sheets). Geological Survey of Vietnam, Hanoi.

HAGGMAN, J., 1994. Gold exploration success in the Philippines, the Didipio project. *In:* Robinson, D., convener, *Proceedings of the I.I.R. Conference, Sydney*, July.

HALL, R., 1995. Plate tectonic reconstructions of the Indonesian region. *In:* Proceedings of the Twenty-Fourth Annual Convention, Indonesian Petroleum Association, Jakarta, 10–12 October 1995, 71–84.

HAMILTON, W., 1979. Tectonics of the Indonesian region. *U.S. Geological Survey, Professional Paper 1078*, 345p.

HENLEY, R.W. AND ELLIS, A.J., 1983. Geothermal systems, ancient and Modern. *Earth Sci. Rev.*, *19*, 1–50.

HODGSON, C.J., 1993. Mesothermal lode-gold deposits. *In:* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I. and Duke, J.M. (Eds.), *Mineral Deposit Modeling*, 635–678.

HUTCHISON, C.S., 1989. Geological Evolution of Southeast Asia. *Oxford Monographs on Geology and Geophysics, 13*, 368p.

IRIANTO, B. AND CLARK, G.H., 1995. The Batu Hijau porphyry copper-gold deposit, Sumbawa Island, Indonesia. *In:* Mauk, J.L. and St. George, J.D. (Eds.), *Proceedings of the 1995 Pacrim Congress, Auckland, New Zealand*, 19–22 November 1995, 299–304.

ISMI, 1993. 1993 Annual Report, Itogon-Suyoc Mining Incorporated.

IZAWA, E., URASHIMA, Y., IBARAKI, K., SUZUKI, R., YOKOYAMA, T., KAWASAKI, K., KOGA, A. AND TAGUCHI, S., 1990. The Hishikari gold deposit: high-grade epithermal veins in Quaternary volcanics of southern Kyushu, Japan. *In:* Hedenquist, J.W., White, N.C. and Siddeley, G. (Eds.), *Epithermal gold mineralization of the circum-pacific, Vol. II*, 1–56.

KAVALIERIS, I., 1988. The characteristics of epithermal mineral occurrences in the Bengkulu Province, Sumatra. *In:* Bicentennial Gold 88, Geological Society of Australia, Abstracts No. 23, 316.

KAVALIERIS, I., WALSHE, J.L., HALLEY, S. AND HARROLD, B.P., 1990. Dome related gold mineralization in the Pani volcanic complex, North Sulawesi, Indonesia: a study of geologic relations, fluid inclusions, and chlorite compositions. *Econ. Geol.*, *85*, 1208–1225.

KHIN ZAW, 1994. Exploration potential of copper-gold and gold-silver deposits in Myanmar, unpublished report submitted to Newmont (Thailand) Limited, 40p.

KOSAKA, H. AND WAKITA, K., 1978. Some geologic features of the Mamut porphyry copper deposit, Sabah, Malaysia. *Econ. Geol.*, *73*, 618–627.

LCMC, 1994. 1994 Annual Report, Lepanto Consolidated Mining Company.

LCMC, 1995. 1995 Annual Report, Lepanto Consolidated Mining Company.

LEACH, T.M. AND CORBETT, G.J., 1995. Characteristics of low sulphidation gold-copper systems in the South-West Pacific. *In:* Mauk, J.L. and St. George, J.D. (Eds.), *Proceedings of the 1995 Pacrim Congress, Auckland, New Zealand*, 19–22 November 1995, 327–332.

LEE, A.K., FOO, K.Y. AND ONG, W.S., 1986. Gold Mineralization and Prospects in North Pahang, Peninsular, Malaysia. Geological Survey of Malaysia, 99p.

LOWDER, G.G. AND DOW, J.A.S., 1978. Geology and exploration of porphyry copper deposits in North Sulawesi, Indonesia. *Econ. Geol.*, *73*, 627–644.

LOWELL, J.D. AND GUILBERT, J.M., 1970, Lateral and vertical alteration-mineralization zoning in porphyry ore deposits: *Econ. Geol.*, *65(4)*, 373–408.

MALIHAN, T.D., 1987. The gold-rich Dizon porphyry copper mine in the western central Luzon Island, Philippines: Its geology and tectonic setting. *In:* Proceedings Pacific Rim Congress 87, Australasian Institute of Mining and

Metallurgy, Victoria, 303–307.

MacDonald, G.D. and Arnold, L.C., 1994. Geological and geochemical zonation of the Grasberg Intrusive Complex, Irian Jaya, Indonesia. *In:* van Leeuwen, T.M., Hedenquist, J.W., James, L.P. and Dow, J.A.S. (Eds.), Indonesian Mineral Deposits — Discoveries of the Past 25 Years. *J. Geochem. Explor., 50*, 143–178.

MMAJ, 1977. Report on geological survey of northeastern Luzon, Phase III. Metal Mining Agency of Japan and Japan International Cooperation Agency, Tokyo, 280p.

MMAJ, 1985. Report on the Collaborative Mineral Exploration of the Bau District, West Sarawak. Consolidated Report, Metal Mining Agency of Japan and Japan International Cooperation Agency, Tokyo.

MMC, 1993. 1993 Annual Report, Manila Mining Corporation.

MMC, 1994. 1994 Annual Report, Manila Mining Corporation.

Meinert, L.D., 1993. Igneous petrogenesis and skarn deposits. *In:* Kirkham, R.V. and Sinclair, W.D., Thorpe, R.I. and Duke, J.M. (Eds.), *Mineral Deposit Modeling*, 569–584.

Meldrum, S.J., Aquino, R.S., Gonzales, R.I., Burke, R.J., Suyadi, A., Irianto, B. and Clarke, D.S., 1994. The Batu Hijau porphyry copper-gold deposit, Sumbawa Island, Indonesia. *In:* van Leeuwen, T.M., Hedenquist, J.W., James, L.P. and Dow, J.A.S. (Eds.), Mineral deposits in Indonesia — Discoveries of the Past 25 years. *J. Geochem. Explor., 50*, 203–220.

Mercado, A., Estoque, J., Lodringueza, L.A., and Ribillion, F.C., 1987a. Geology and ore deposits of Masara mine, Davao del Norte, Philippines. *In:* Proceedings Pacific Rim Congress 87. Australasian Institute of Mining and Metallurgy, Victoria, 329–332.

Mercado, A., Estoque, J., Domingo, B., Acenes, M. and Abaigar, J., 1987b. Geology and ore genesis of the Siana gold-silver Deposit, Surigao del Norte, Philippines. *In:* Proceedings Pacific Rim Congress 87. Australasian Institute of Mining and Metallurgy, Victoria, 325–328.

Mertig, H.J., Rubin, J.N. and Kyle, J.R., 1994. Skarn Cu-Au ore bodies of the Gunung Bijih (Ertsberg) district, Irian Jaya, Indonesia. *In:* van Leeuwen, T.M., Hedenquist, J.W., James, L.P. and Dow, J.A.S. (Eds.), Mineral deposits in Indonesia — Discoveries of the Past 25 years. *J. Geochem. Explor., 50*, 179–202.

Metals Economics Group, 1994. Gold acquisition service: worldwide gold projects and mines database. Metals Economics Group, Halifax, Nova Scotia.

Meyer, C. and Hemley, J.J., 1967. *In:* Barnes, H.L. (Ed.), Geochemistry of Hydrothermal Ore Deposits. Wall Rock Alteration, 166–235.

Mining Journal, 25 Jun 1993. Mining Finance; 470. Benquet bites the bullet.

Mining Journal, 20 Aug 1993. Industry in Action; Exploration, 120.

Mining Journal, 14 Oct 1994. Mining week, 272. Funds for Guinaoang deposit.

Mining Journal, 11 Nov 1994. Industry in Action; Development, 341. LFT in second Philippine development.

Mining Journal, 16 Dec 1994a. Country Supplement; Malaysia exploration and development, 6.

Mining Journal, 16 Dec 1994b. Country Supplement; Malaysia exploration and development, 8.

Mining Journal, 6 Oct 1995. Mining week, 251. Grasberg bonanza.

Mining Journal, 15 Dec 1995. Focus and Comment, 460. Momentum mounts in Philippines.

Mining Journal, 22 Dec 1995. Mining week, 475. Emerging gold producers.

Mining Review, June 1992. Countries; Far East; 99. Malaysia.

Minproc, 1985. The Kyaukpahto Project — Burma. *Definitive engineering study prepared for the Australasian Mineral Development Laboratories*, Volume I. Unpublished report. Mining and Process Engineering Services Pty. Ltd.

Mitchell, A.H.G. and Balce, G.R., 1990. Geologic features of some epithermal gold systems, Philippines. *In:* Hedenquist, J.W., White, N.C. and Siddeley, G. (Eds.), Epithermal Gold Mineralization of the Circum-Pacific: Geology, Geochemistry, Origin and Exploration, I.J. *Geochem. Explor., 35*, 241–296.

Mitchell, A.H.G. and Leach, T.M., 1991. Epithermal Gold in the Philippines. Academic Press, London, 457p.

Newcrest Mining, 28 May 1996. Quarterly Report to the Australian Stock Exchange.

Newmont Mining, 1994. 1994 Annual Report, Newmont Mining Corporation.

Niugini Mining, 1994. 1994 Annual Report, Niugini Mining Limited.

Nguyen Van Chu, 1991. On the productive mineralization stages and characteristic mineral associations of primary gold deposits and occurrences of Vietnam. *In:* Proceedings of the Southeast Asia Gold Symposium, 1, 15–18.

Ohmoto, H. and Skinner, B.J., 1983. The Kuroko and Related Volcanogenic Massive Sulfide Deposits: Introduction and summary of new findings. *In:* Economic Geology Monograph 5, 1–8.

Percival, T.J., Bagby, W.C. and Radtke, A.S., 1990. Physical and chemical features of precious metal deposits hosted by sedimentary rocks in the western United States. *In:* Raines, G.L., Lisle, R.E., Schafer, R.W. and Wilkenson, W.H. (Eds.), Geology and Ore Deposits of the Great Basin. *Geol. Soc. of Nevada, Symposium Proceedings, Reno*, 11–34.

Perello, J.A., 1994. Geology, porphyry Cu-Au, and epithermal Cu-Au-Ag mineralization of the Tombulilato district, North Sulawesi, Indonesia. *In:* van Leeuwen, T.M., Hedenquist, J.W., James, L.P. and Dow, J.A.S. (Eds.), Mineral deposits in Indonesia — Discoveries of the Past 25 years. *J. Geochem. Explor., 50*, 221–256.

Philex, 1995. Bulawan deposit poster presentation at GEOSEA Conference in Manila, Philippines 14–18 February, 1995.

Richards, J.P. and Kerrich, R., 1993. The Porgera gold mine, Papua New Guinea: Magmatic hydrothermal to epithermal evolution of an alkalic-type precious metal deposit. *Economic Geology, 88*, 1017–1052.

Richardson, J.A., 1939. The geology and mineral resources of the neighbourhood of Raub, Pahang, Federated Malay States, with an account of the geology of the Raub Australian Gold Mine. *Geological Survey Department Memoir 3.*

Schuh, W.D., 1993. *Geology, Geochemistry and Ore Deposits of the Bau Gold Mining District, Sarawak, Malaysia.* Unpublished Ph.D. thesis, The University of Arizona, 315p.

Sewell, D.M. and Wheatley, C.J.V., 1994. The Lerokis and Kali Kuning submarine exhalative gold-silver-barite deposits, Wetar Island, Maluku, Indonesia. *In:* van

Leeuwen, T.M., Hedenquist, J.W., James, L.P. and Dow, J.A.S. (Eds.), Mineral Deposits in Indonesia — Discoveries of the Past 25 Years. *J. Geochem. Explor., 50,* 351–370.

SHAWE, D.R., 1984. Geology and Mineral Deposits of Thailand. *U.S. Geological Survey Open File Report* 84–403, 190p.

SILLITOE, R.H. AND GAPPE, I.M., JR., 1984. Philippine Porphyry Copper Deposits: Geologic Setting and Characteristics. *United Nations ESCAP, CCOP Technical Publication No. 14,* 89p.

SILLITOE, R.H. AND ANGELES, C.A., JR., 1985. Geological characteristics and evolution of a gold-rich porphyry copper deposit at Guinaoang, Luzon, Philippines. *In:* Asian Mining 1985. Instn. Min. Metall., London, 15–26.

SILLITOE, R.H., ANGELES, C.A., JR., COMIA, G.M., ANTIOQUIA, E.C. AND ABEYA, R.E., 1990. An acid-sulphate-type lode gold deposit at Nalesbitan, Luzon, Philippines. *In:* Hedenquist, J.W., White, N.C. and Siddeley, G. (Eds.), *Epithermal gold mineralization of the circum-pacific,* Vol. I, 387–412.

SIMMONS, S.F. AND BROWNE, P.R.L., 1990. Mineralogic, alteration and fluid-inclusion studies of epithermal gold-bearing veins at the Mt. Muro Prospect, Central Kalimantan (Borneo), Indonesia. *In:* Hedenquist, J.W., White, N.C. and Siddeley, G. (Eds.), *Epithermal gold mineralization of the circum-pacific, Vol. I,* 63–104.

SWIFT, L.R. AND ALWAN, M., 1990. Discovery of gold-silver mineralization at Binebase, Sangihe Island, Indonesia. *In:* Proceedings Pacific Rim Congress 90, Vol. 2. Australasian Institute of Mining and Metallurgy, Parkville, 533–539.

TAN, L.P., 1991. The Chinkuashih gold-copper deposits, Taiwan. *Society of Economic Geologists Newsletter, 7,* 21–24.

TEOH, L.H., LEE, A.K. AND FOO, K.Y., 1987. Gold mineralization and prospects in Kelantan, Peninsular Malaysia, 127p. Geological Survey of Malaysia.

TURNER, S.J., FLINDELL, P.A., HENDRI, D., HARDJANA, I., LAURICELLA, P.F., LINDSAY, R.P., MARPAUNG, B. AND WHITE, G.P., 1994. Sediment-hosted gold mineralization in the Ratatotok district, North Sulawesi, Indonesia. *In:* van Leeuwen, T.M., Hedenquist, J.W., James, L.P. and Dow, J.A.S. (Eds.), Mineral Deposits in Indonesia — Discoveries of the Past 25 Years. *J. Geochem. Explor., 50,* 317–336.

TVI PACIFIC INC., 1995. Information memorandum, TVI Pacific Incorporated.

UNDP, 1978. Geological survey and exploration, Burma: Project findings and recommendations, PD/UN/BUR-72-002/9, United Nations Development Program, 24p.

UNDP, 1987a. Geology and mineralization in the Panganiban-Tabas and Bulala areas, Camarines Norte. Technical Report No. 1, DP/UN/PHI-85-001/1, United Nations Development Programme, New York, 43p.

UNDP, 1987b. Geology and gold mineralization of Surigao del Norte. Technical Report No. 4, DP/UN/PHI-85-001/4, United Nations Development Programme, New York, 60p.

UNDP, 1992. The Philippines: A Prospectus for the International Mining Industry, 226p.

UNITED NATIONS, 1990a. Atlas of Mineral Resources of the ESCAP Region, volume 6, Vietnam. Explanatory Brochure, 124p.

UNITED NATIONS, 1990b. Atlas of Mineral Resources of the ESCAP Region, volume 7, Lao Peoples Democratic Republic. Explanatory Brochure, 19p.

UNITED NATIONS, 1993. Atlas of Mineral Resources of the ESCAP Region, volume 10, Cambodia. Explanatory Brochure, 87p.

VAN BEMMELEN, R.S., 1949. *The Geology of Indonesia, Vol. II, Economic Geology.* Govt. Printing Office, The Hague, 265p.

VAN LEEUWEN, T.M., 1994. 25 years of mineral exploration and discovery in Indonesia. *In:* van Leeuwen, T.M., Hedenquist, J.W., James, L.P. and Dow, J.A.S. (Eds.), Mineral Deposits in Indonesia — Discoveries of the Past 25 Years. *J. Geochem. Explor., 50,* 13–90.

VAN LEEUWEN, T.M., HAWKE, A., LEACH, T. AND HAWKE, M., 1990. The Kelian disseminated gold deposit, East Kalimantan, Indonesia. *In:* Hedenquist, J.W., White, N.C. and Siddeley, G. (Eds.), Epithermal Gold Mineralization of the Circum-Pacific: Geology, Geochemistry, Origin and Exploration, *I.J. Geochem. Explor., 35,* 1–62.

VAN DER PLOEG, F.P.C.S., 1945. Insulinde, Schatten van den Bodem. W. van Hoeve, Deventer, 216p (in Dutch).

WHITE, N.C. AND HEDENQUIST, J.W., 1995. Epithermal Gold Deposits: Styles, Characteristics and Exploration. *In:* Society of Economic Geologists Newsletter, October 1995, No. 23.

WHITE, N.C., LEAKE, M.J., MCCAUGHEY, S.N. AND PARRIS, B.W., 1995. Epithermal gold deposits of the southwest Pacific. *In: Journal of Geochemical Exploration, 54(2),* October 1995, 87–136.

WILFORD, G.E., 1955. The Geology and Mineral Resources of the Kuching-Lundu Area Including the Bau Mining District, British Territories in Borneo Geological Survey Memoir 3, 65p.

WILLIAMSON, A. AND FLEMING, G.J., 1995. Miwah prospect high sulphidation Au-Cu mineralisation, northern Sumatra, Indonesia. *In:* Mauk, J.L. and St. George, J.D. (Eds.), *Proceedings of the 1995 Pacrim Congress, Auckland, New Zealand,* 19–22 November 1995, 637–642.

WOLFENDEN, E.B., 1965. Bau Mining District, West Sarawak, Malaysia. Part I: Bau. Geological Survey, Borneo Region, Malaysia. Bulletin 7, 147p.

WU, I.J., 1994. Recent gold exploration at Chinkuashih Cu-Au deposit, Taiwan. An invited paper presented at the National Western Mining Conference and Exhibition, Denver, Colorado, 18p.

YAN, A., 1990. Features of volcanic-hosted epithermal gold mineralization in the Nagos and Mantri areas, Semporna Peninsula, Eastern Sabah. *Report No. SB 91/1, Jabatan Kajibumi Malaysia,* 19p.

YE MYINT SWE, 1990. Geology and gold mineralization at Kyaukpahto mine area, Kawlin Township. Unpublished M.Sc thesis, Yangon University, Yangon.

YEAP, E.B., 1988. Gold mineralization in the Central Belt of Peninsular Malaysia. *In:* Goode, A.D.T., Smyth, E.L., Birth, W.D. and Bosme, L.I. (Eds.), *Bicentennial Gold 88.* Extended Abstracts Poster Programme Vol. 1, 238–242.

YUMUL, G.P., 1980. Casenana Project description, in Cordillera Central Region: Its geology and mineral resources-province of Benquet, Bureau of Mines and Geosciences-Ministry of Natural Resources, 62p.

*Manuscript received 30 May 1996*

**Appendix 1.** Significant gold and gold-copper deposits of Indonesia.

| Deposit (1) | Abbreviation | Style (2) | Magmatic Arc | Region/District | Contained Metal (3) | | Reference for Contained Metal (4) |
|---|---|---|---|---|---|---|---|
| | | | | | Cu (000's mT) | Au (mT) | |
| Grasberg (Reserve) * | GBR | PO CGD | Medial Irian Jaya | Carstenz | 14638 | 1599 | Freeport - McMoran Mining, 1994 |
| Batu Hijau | BH | PO CGD | Banda | West Sumbawa | 5612 | 469 | Newmont Mining, 1994 |
| Cabang Kiri East | CE | PO CGD | North Sulawesi | Gorontalo | 585 | 79 | van Leeuwen, 1994 |
| Sungai Mak | SM | PO CGD | North Sulawesi | Gorontalo | 638 | 33 | van Leeuwen, 1994 |
| Kayubulan Ridge | KR | PO CGD | North Sulawesi | Gorontalo | 570 | 25 | van Leeuwen, 1994 |
| Kaputusan | KP | PO CGD | Halmahera | Bacan | 210 | 15 | van Leeuwen, 1994 |
| Bulagidun | BG | PO CGD | North Sulawesi | Marissa | 88 | 10 | van Leeuwen, 1994 |
| Ertsberg East (IOZ/DOZ)* | EBE | SK | Medial Irian Jaya | Carstenz | 2151 | 79 | Mertig et al, 1994 |
| Wabu | WB | SK | Medial Irian Jaya | Carstenz | | 62 | Mining Journal, 6 Oct. 1995; Potter, pers. comm., 1996 (min. estimate) (6) |
| Big Gossan | BGO | SK | Medial Irian Jaya | Carstenz | 480 | 23 | van Leeuwen, 1994 |
| Ertsberg * | EB | SK | Medial Irian Jaya | Carstenz | 750 | 26 | Mertig et al, 1994 |
| Dom * | DOM | SK | Medial Irian Jaya | Carstenz | 464 | 12 | Mertig et al, 1994 |
| Awak Mas | AM | QL | Arc unrelated | Awak Mas, Central Sulawesi | | 26 | van Leeuwen, 1994 |
| Kelian * | KE | CB | Central Kalimantan | Central Kalimantan | | 179 | van Leeuwen, 1994 |
| Busang-Southeast Zone | BUS | CB | Central Kalimantan | Central Kalimantan | | 172 | George Cross Newsletter, 18 Apr. 1996 (measured/indicated only) |
| Busang-Central Zone | BUC | CB | Central Kalimantan | Central Kalimantan | | 82 | George Cross Newsletter, 18 Apr. 1996 (minor inferred included) |
| Bawone (Binebase) | BA | EP HS | Sangihe | Sangihe | | 6 | van Leeuwen, 1994 |
| Gn. Pongkor * | PG | EP LS | Sunda | West Java | | 103 | van Leeuwen, 1994 |
| Mount Muro * | MM | EP LS | Central Kalimantan | Central Kalimantan | | 47 | Mining Journal, 22 Dec. 1995 |
| Lebong Tandai * | LT | EP LS | Sunda | Bengkulu | | 43 | van Leeuwen, 1994 |
| Lebong Donok * | LD | EP LS | Sunda | Bengkulu | | 41 | van Leeuwen, 1994 |
| Gn. Pani | PN | EP LS | North Sulawesi | Marissa | | 41 | van Leeuwen, 1994; Carlile and Mitchell, 1994 |
| Gosowong | GO | EP LS | Halmahera | Gosowong | | 29 | Newcrest Mining, 28 Mar. 1996 |
| Lanut * | LN | EP LS | North Sulawesi | Kotamobagu | | 27 | van Leeuwen, 1994 |
| Doup | DP | EP LS | North Sulawesi | Kotamobagu | | 19 | van Leeuwen, 1994 |
| Rawas | RW | EP LS | Sunda | Bengkulu | | 15 | Metals Economics Group, 1994 |
| Bolangitang | BO | EP LS | North Sulawesi | Gorontalo | | 11 | Carlile and Mitchell, 1994 (6) |
| Toka Tindung | TO | EP LS | North Sulawesi | Kotamobagu | | 9 | Aurora Mining, 27 May 1996 |
| Mirah | MI | EP LS | Central Kalimantan | Central Kalimantan | | 8 | van Leeuwen, 1994 |
| Sungai Keruh | SR | EP LS | Meratus-Sumatra | Meratus | | 8 | van Leeuwen, 1994 |
| Cikondang | CI | EP LS | Sunda | West Java | | 8 | van Leeuwen, 1994 (5) |
| Mangani * | MG | EP LS | Sunda | Mangani | | 6 | van Leeuwen, 1994 (5) |
| Mesel Deposits * | ME | DS | North Sulawesi | Kotamobagu | | 62 | Newmont Mining, 1994 |
| Wetar Deposits * | WT | MS/EP HS | Banda | Wetar | | 23 | van Leeuwen, 1994 |

(1) – (6) Explanations are included in Appendix 2

**Appendix 2.** Significant gold and gold-copper deposits of Philippines.

| Deposit (1) | Abbreviation | Style (2) | Magmatic Arc | Region/District | Contained Metal (3) | | Reference for Contained Metal |
|---|---|---|---|---|---|---|---|
| | | | | | Cu (000's mT) | Au (mT) | |
| Far South East | FSE | PO CGD | Luzon Central Cordilerra | Mankayan | 2599 | 441 | Mitchell and Leach, 1991 |
| Sto Thomas II * | TH | PO CGD | Luzon Central Cordillera | Baguio | 1125 | 222 | Baluda and Galapan, 1993 |
| Kingking | KK | PO CGD | Philippines | Camarines Norte | 1386 | 164 | Mining Journal, 25 Jun. 1993 |
| Guinaoang | GU | PO CGD | Luzon Central Cordillera | Mankayan | 1206 | 121 | Mining Journal, 14 Oct. 1994 |
| Dinkidi | DK | PO CGD | Cordon | Isabela-Didipio | 432 | 108 | Mining Journal, 15 Dec. 1995 |
| Dizon * | DZ | PO CGD | Western Luzon | Zambales | 602 | 130 | Malihan, 1987 |
| Lobo * | LB | PO CGD | Luzon Central Cordillera | Baguio | 588 | 53 | Sillitoe and Gappe, 1984 |
| Amacan * | AC | PO CGD | Philippines | Masara | 429 | 46 | Sillitoe and Gappe, 1984 |
| Tayson | TY | PO CGD | Western Luzon | Batangas | 500 | 42 | Sillitoe and Gappe, 1984 |
| Santo Nino * | SN | PO CGD | Luzon Central Cordillera | Baguio | 425 | 33 | Sillitoe and Gappe, 1984 |
| Mapula | MP | PO CGD | Philippines | Masara | 312 | 28 | Sillitoe and Gappe, 1984 |
| Batong Buhay * | BB | PO CGD | Luzon Central Cordillera | Northwest Luzon | 642 | 27 | TVI Pacific Inc., 1995 |
| Tawi-Tawi | TT | PO CGD | Luzon Central Cordillera | Bobok | 620 | 25 | MMAJ, 1977 |
| Tapian * | TA | PO CGD | Sierra Madre | Marinduque | 920 | 21 | Sillitoe and Gappe, 1984 |
| San Antonio | SA | PO CGD | Western Luzon | Marinduque | 1112 | 20 | Sillitoe and Gappe, 1984 |
| Black Mountain * | BM | PO CGD | Luzon Central Cordillera | Baguio | 236 | 20 | Sillitoe and Gappe, 1984 |
| Gambang | GA | PO CGD | Luzon Central Cordillera | Mankayan | 195 | 18 | Yumul, 1980 |
| Suluakan (Worldwide) | SL | PO CGD | Luzon Central Cordillera | Baguio | 431 | 16 | Sillitoe and Gappe, 1984 |
| Botilao | BT | PO CGD | Luzon Central Cordillera | Northwest Luzon | 428 | 16 | Sillitoe and Gappe, 1964 |
| Ullman * | UL | PO CGD | Luzon Central Cordillera | Baguio | 129 | 13 | Sillitoe and Gappe, 1984 |
| Dilong/Hale | HA | PO CGD | Luzon Central Cordillera | Northwest Luzon | 175 | 12 | Sillitoe and Gappe, 1984 |
| Pisumpan | PI | PO CGD | Western Luzon | Zambales | 82 | 12 | Sillitoe and Gappe, 1984 |
| San Fabian | SF | PO CGD | Luzon Central Cordillera | San Fabian | 135 | 10 | Sillitoe and Gappe, 1984 |
| Marian | MA | PO CGD | Cordon | Isabela-Didipio | 200 | 10 | Sillitoe and Gappe, 1984 |
| Lutopan * | LT | PO CGM | Cebu | Cebu | 2665 | 165 | Sillitoe and Gappe, 1984 |
| Biga * | BI | PO CGM | Cebu | Cebu | 1699 | 99 | Sillitoe and Gappe, 1984 |
| Carmen * | CA | PO CGM | Cebu | Cebu | 1677 | 94 | Sillitoe and Gappe, 1984 |
| Larap (Matanlang) | LA | PO CGM | Philippines | Camarines Norte | 227 | 26 | Sillitoe and Gappe, 1984 |
| Thanksgiving * | TG | SK | Luzon Central Cordillera | Baguio | | 13 | Mitchell and Leach, 1991 |
| Bulawan * | BL | CB | Masbate-Negros | Negros | | 41 | Metals Economics Group, 1994 |

**Appendix 2.** Significant gold and gold-copper deposits of Philippines (cont'd).

| Deposit (1) | Abbreviation | Style (2) | Magmatic Arc | Region/District | Contained Metal (3) | | Reference for Contained Metal (4) |
|---|---|---|---|---|---|---|---|
| | | | | | Cu (000's mT) | Au (mT) | |
| Lepanto * | LP | EP HS | Luzon Central Cordillera | Mankayan | 856 | 132 | LCMC, 1994; LCMC, 1995 |
| Nalesbitan * | NA | EP HS | Philippines | Camarines Norte | | 9 | UNDP, 1992 |
| Acupan * | AC | EP LS | Luzon Central Cordillera | Baguio | | 97 | } BMG, 1986; Benquet Corp., 1995 (estimate) |
| Antamok * | AK | EP LS | Luzon Central Cordillera | Baguio | | 315 | } Andam pers. comm., 1996; Benquet Corp., 1994 (estimate) |
| Itogon * | IT | EP LS | Luzon Central Cordillera | Baguio | | 122 | ISMI, 1993; ISMI, 1979 and 1994 (estimate) |
| Placer * | PL | EP LS | Philippines | Surigao | | 65 | MMC, 1993; MMC, 1994; Mitchell and Leach, 1991 (estimate) |
| Masbate * | MB | EP LS | Masbate-Negros | Masbate | | 62 | Mitchell and Leach, 1991 (estimate) |
| Longos PT * | LG | EP LS | Philippines | Camarines Norte | | 38 | UNDP, 1992 |
| Masara * | MS | EP LS | Philippines | Masara | | 34 | Mitchell and Leach, 1991; White et al, 1995 |
| Runruno | RR | EP LS | Cordon | Isabela-Didipio | | 19 | Mining Journal, 11 Nov. 1994 |
| Batong Buhay * | BBE | EP LS | Luzon Central Cordillera | Northwest Luzon | | 13 | TVI Pacific Inc., 1995 |
| Co-o * | CO | EP LS | Philippines | Central East Mindanao | | 7 | UNDP, 1992 (5) |
| Siana * | SI | DS/EP LS | Philippines | Surigao | | 26 | BMG, 1986; Mitchell and Leach, 1991 (estimate) |
| Sulat | SU | MS | Philippines | Central Samar | 198 | 20 | Philippines BMG, 1986 |

**Notes for Appendices 1-3:**

(1) Present or historic mines are indicated by *
(2) Explanation indicated below
(3) Includes combined resources and past production
(4) Deposits in which an estimate is made concerning gold grade and/or deposit size are indicated
(5) Deposit size <1.0 million tonnes, not indicated in Figs. 14-17
(6) Deposits where accurate grade-tonnage figures are not available, not indicated on Figs. 14-17

**Explanation for mineralization styles, Appendices 1 - 3:**

PO CGD = porphyry copper-gold
PO CGM = porphyry copper-molybdenum-gold
SK = skarn
CB = carbonate-base metal-gold
EP HS = high-sulfidation epithermal
EP LS = low-sulfidation epithermal
QL = quartz lode
MS = massive sulfide or exhalative
DS = disseminated sediment-hosted

**Appendix 3.** Significant gold and gold-copper deposits of other Southeast Asian countries.

| Deposit (1) | Abbreviation | Style (2) | Belt/Arc | Region/District | Contained Metal (3) | | Reference for Contained Metal (4) |
|---|---|---|---|---|---|---|---|
| | | | | | Cu (000's mT) | Au (mT) | |
| **MALAYSIA** | | | | | | | |
| Mamut * | MT | PO CGD | Kinsbalu Pluton | Mamut - Nungkok | 859 | 90 | Kosaka and Wakita, 1978 |
| Mengapur | MR | PO CGM/SK | Malayan Eastern Belt | Sungai Luit | 812 | 27 | Mining Journal, 16 Dec. 1994a |
| Raub * | RB | QL | Malayan Central Belt | Raub - Kuala Lipis | | 30 | Lee et.al., 1986 (estimate) |
| Penjom | PJ | QL | Malayan Central Belt | Raub - Kuala Lipis | | 10 | Mining Journal, 16 Dec. 1994b |
| Tai Parit * | TP | DS | Central Kalimantan Arc | Bau | | 18 | Cox, 1992 |
| Jugan | JU | DS | Central Kalimantan Arc | Bau | | 13 | Cox, 1992 (estimate) |
| Ulu Sokor | US | MS | Malayan Central Belt | Ulu Sokor | | 6 | Mining Review, June 1992 |
| **TAIWAN** | | | | | | | |
| Chinkuashih * | CK | EP HS | Ryukyu Arc | Chinkuashih | | 92 | Tan, 1991 |
| **THAILAND** | | | | | | | |
| Loei | LO | SK | Luang Prabang Fold Belt | Loei | | 20 | Metals Economics Group, 1994 |
| **LAO** | | | | | | | |
| Xepon | XP | DS | Troung Son Fold Belt | Tchepone | | 30 | van Leeuwen, pers. comm., 1996 |
| **MYANMAR** | | | | | | | |
| Kyaukpahto * | KY | DS | Eastern Trough to Burman Arc | Kyaukpahto - Indawgyi | | 15 | Minproc, 1985 |
| **VIETNAM** | | | | | | | |
| Sin Quyen | SQ | SK | Da River Mobil Belt | Sin Quyen | 956 | 46 | Mining Journal, 20 Aug. 1993 |
| Nui Kem * | NK | QL | Kontum Massif | Bong Mieu | | 6 | Baxter et. al., 1991 (estimate) |
| **KAMPUCHEA** | | | | | | | |
| Bo Sup Trup * | BT | QL | Siem Reap Fold Belt | Sam Ra Ong | | 6 | Fontaine and Workman, 1978 (5) |

(1) – (6) Explanations are included in Appendix 2

**Appendix 4.** Historic production and reserve figures for selected gold mines of the Philippines.

| Deposit | Historic Production Au (mT) | Reserve (2) Au (mT) | Total Au (mT) | Present Owner |
|---|---|---|---|---|
| Lepanto | 119 (to 1995) | 13 | 132 | Lepanto Consolidated Mining Co. |
| Acupan | 84 (to 1958) | 13 | 97 | Benguet Corporation |
| Antamok (1) | 301 (to 1995) | 14 | 315 | Benguet Corporation |
| Itogon | 44 (to 1993) | 78 | 122 | Itogon-Suyoc Mining Inc. |
| Placer | 11 (to 1994) | 54 | 65 | Manila Mining Corporation |
| Masbate | 40 (to 1940) | 22 | 62 | Atlas Consolidated Mining and Development |
| Masara | 5 (to 1982) | 28 | 34 | London Fiduciary Trust |
| Siana | 5 (to 1967) | 21 | 26 | Surigao Consolidated Mining |

*Note:* References are as indicated in Appendix 2.
(1) Includes production from Acupan from 1958–1992.
(2) Figures indicate those reserves additional to past production.